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A Study of diversity in egyptian cotton

O. F. Cook, Argyle McLachlan, Rowland Montgomery Meade

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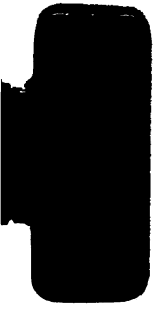

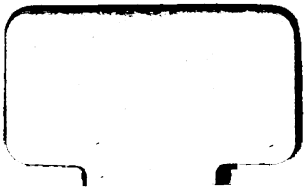

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 156.

B. T. GALLOWAY, *Chief of Bureau.*

41

A STUDY OF DIVERSITY IN EGYPTIAN COTTON.

BY

O. F. COOK, ARGYLE McLACHLAN, AND ROWLAND M. MEADE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 8, 1909.

Sir: I have the honor to transmit herewith a paper entitled "A Study of Diversity in Egyptian Cotton," by Messrs. O. F. Cook, Argyle McLachlan, and Rowland M. Meade, of this Bureau, and recommend its publication as Bulletin No. 156 of the Bureau series.

This Bureau has conducted experiments with Egyptian cotton at Yuma, Ariz., for several years past, under the direction of Mr. T. H. Kearney. The results have been increasingly favorable. In the season of 1907 the cotton was so good, both in yield and in quality, as to justify our calling attention to this crop in Bulletin No. 128 of this Bureau as likely to prove suited to cultivation in the irrigated districts of Arizona and adjacent States.

In the season of 1908 the results were somewhat less favorable, though by no means discouraging. The planting of the cotton in other localities in Arizona and southern California showed that the acclimatization, which appeared to be well advanced at Yuma last year, is not sufficiently complete to insure normal behavior of the plants in other places. And even at Yuma the cotton of this season showed an appreciable deterioration, affecting the yield as well as the length and uniformity of the fiber.

As soon as these unfavorable tendencies became apparent Mr. Kearney asked that they be made the subject of special study to ascertain their nature and causes. Mr. Cook and his assistants were assigned to this work because they had become familiar with the behavior of cotton during the period of acclimatization, in connection with the weevil-resistant Central American cottons recently introduced into Texas. The present report contains the results of their investigations. It shows that the deterioration can be traced to the existence of several forms of diversity among the plants, and that cultural practices as well as factors of breeding and acclimatization must be taken into account in order to secure the necessary uniformity of the product.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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A STUDY OF DIVERSITY IN EGYPTIAN COTTON.

INTRODUCTION.

The diversity found in the Egyptian cotton in Arizona appears to be of four different kinds, evidently arising from different physiological factors. Precautions which may tend to avoid one kind of diversity will not be fully effective unless other factors are taken into account at the same time. Methods of acclimatization, breeding, and culture have all to be adapted to the special needs of the case if the full possibilities of the new crop are to be definitely ascertained.

The first and most striking kind of diversity is due to hybridization. The cross-fertilizing insects are much more abundant and active in our Southwestern States than in any other cotton-growing region thus far investigated. This will render it impossible to maintain a culture of pure Egyptian or other high-grade cotton unless all other kinds of cotton are excluded from the localities in which superior stocks are planted. Though the lint of the hybrid plants is often superior to that of the pure Egyptian plants, it is sufficiently different to interfere with the commercial uniformity of the product.

The second kind of diversity that affects the Egyptian cotton is evidently due to incomplete acclimatization. As with other types of cotton, transfer to new conditions induces great variation, not only in the habits of growth and other vegetative characters of the plants, but also in fertility and in the abundance and length of the lint. This form of diversity is to be eliminated by the selection each year of the plants that approach most nearly to the normal form of the variety, are the most fertile, and have the best lint.

The third kind of diversity is more directly connected with differences in the physical environment which cause or call forth differences in the individual plants. It is shown most strikingly in comparing the behavior of the plants in the different localities, but includes also some of the differences that occur in the same locality or in different parts of the same field. This form of diversity is familiar in all branches of agriculture, but is greater with a newly introduced variety, and may be expected to decrease as a better adjustment to the new conditions is attained. The second kind of diversity represents incomplete acclimatization, while the third kind is more closely connected with the phenomenon of accommodation.

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The fourth kind of diversity is shown in the different parts of the same plant and is often very pronounced, especially in the characters of the lint. If the plants become too luxuriant, fruiting is deferred till late in the season or the early bolls remain poorly developed and produce a very weak fiber. To avoid this form of diversity, a proper relation has to be established between the habits of growth of the plants and the methods of culture and irrigation. Sudden changes in the rate of growth are particularly to be avoided as tending to produce fluctuations in the fertility of the plants and in the commercial quality of the lint.

The principal reason why diversity has such serious effects upon the yield of lint is found in the habit of the cotton plant to produce two types of branches which are quite distinct in form and function. Slight differences of external conditions which might have very little direct effect upon the size and vigor of the plant are able to induce relatively great differences in the yield by inducing a preponderance of the sterile, vegetative form of branches over the fertile form.

EGYPTIAN COTTON RELATED TO AMERICAN VARIETIES.

The cultivated varieties of cotton appear to fall into two series. Varieties native in America find their nearest relatives in other New World varieties, and all appear to be widely distinct from the indigenous species of Asia and Africa. Though very different from the Upland varieties of the United States, the Egyptian cotton and the Sea Island cottons are also native of tropical America and are not so fundamentally different from the Upland cottons as is often supposed.

No varieties have as yet been discovered which are exactly intermediate between the Egyptian and the Upland types, but many of the Central American and West Indian varieties which are obviously related to our Upland cottons show some of the characteristics of the Egyptian and the Sea Island series. At the same time it has been found that the West Indian and Central American relatives of the Sea Island and Egyptian cottons show many Upland characters. Only a little additional evidence is needed to prove that the native American types of cotton form a continuous series, without any larger breaks than those which serve to separate the very numerous local varieties still kept in cultivation among the agricultural Indians of tropical America. The results of the present study of diversity in Egyptian cotton tend to emphasize the relationships of the American varieties and make it evident that the Egyptian cottons have the same wide range of variation that other American cottons have been known to display.

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NATURE OF DIVERSITIES AROUSED BY NEW CONDITIONS.

Transfer to new conditions has the effect of bringing back into expression many ancestral characters which do not appear when a variety is growing under conditions to which it is thoroughly accustomed. This tendency toward increased diversity under new conditions is not confined to cotton, but is widely prevalent among cultivated varieties of other plants. It is practically recognized in the fact, well-known among gardeners and florists, that the highest grade of seed of many varieties is produced only in the locality where the variety was developed. Everywhere else it appears to deteriorate by reason of the diversity that shows itself in the second or third generations, if not in the first.

The usual statement that the deterioration is due to unfavorable conditions is not a sufficient explanation of the diversity which often constitutes the deterioration. It is not reasonable to suppose that one set of new conditions can be directly responsible for the large number of differences that often appear. It is easier to believe that the new conditions are indirectly responsible for the diversity and that they bring it about by disturbing the heredity of the plants; that is, they disturb the internal adjustments which control the development of the individual plants and thus allow each of the individuals to develop in a different way, as they often appear to do. Even when a whole planting of a newly imported stock appears to change over to a new type quite different from the normal form in the previous environment a notable amount of individual difference is usually to be found, and this diversity may even appear to increase for two or three generations, or until the variety becomes readjusted to normal behavior under the new conditions.

That the new conditions are not directly responsible for the diverse characters that appear is also shown by the fact that different sets of new conditions often call forth closely similar examples of diversity. Different plantings of the same stock bring out the same series of diversities, and there is even a general correspondence between the ranges of diversity shown by different stocks. Features supposed to characterize only one variety are found to crop out in many related varieties. It becomes evident that the diversities, though they may be very extensive and very complex, are not entirely indefinite or at random but fall into parallel and related series, so that it is possible to think of the many newly aroused diversities as representing not new characters but returns to old characters, as though the new conditions had caused the plants to wander from their usual path of development and thus to fail to reach their normal goal.

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DIVERSITY OF RECOGNIZED EGYPTIAN VARIETIES.

Varieties of Egyptian cotton seem to have been known chiefly by differences in the fiber rather than by differences in the plants. Though the Egyptian type of cotton as a whole seems to have a range of variation parallel to that of our Upland series of varieties, only a few varietal forms have been separated and given distinctive names. Much less attention has been given to differences in the vegetative characters of the plants than with our Upland varieties. The larger size and the more open habit of growth make it more difficult to become familiar with the vegetative differences in the Egyptian cotton than in the Upland cottons. In the smaller and more compact Upland plants individual differences can be seen and compared much more readily and are of the greatest assistance in acclimatization and breeding.

Unless we know the normal form of the plants as they grow under accustomed conditions we can not be sure that the selection that we apply to them is really calculated to favor the most prompt adjustment to the new conditions. In the absence of sufficiently definite knowledge of this kind, fertility and the characters of the lint are the only standards of selection that can be applied. If we select too narrowly we may preserve variant forms rather than the usual type of the variety, while if we retain good plants of many forms the intermingling of these may tend to prolong the condition of diversity.

A study of the range of diversity of the newly introduced Egyptian cottons was made for the double purpose of being able to judge of the extent of acclimatization and of securing a better basis for distinguishing hybrids. The same schedule or set of characters was used as a guide in the study of diversity in the plots raised from imported seed as was later employed in the study of the acclimatized stocks and the hybrids. The characters which received the most attention are indicated in greater detail in the latter part of the present report, where the hybrids are considered. The general plan of working with a series of the more definitely contrasted characters in mind had already been developed in the study of hybrids from the standpoint of the Upland types of cotton in Texas, and the work in Arizona was greatly facilitated by this preliminary practice.

It is not improbable, of course, that this method of procedure may have led us to overlook some forms of diversity that did not come within the range of our schedule of characters. On the other hand, it may be claimed that our work was able to give us more definite conclusions because the results of the study of diversity took a form which adapted them directly to the purposes of our inquiry.

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DIVERSITY OF NEWLY INTRODUCED JANNOVITCH COTTON.

Fortunately for the purposes of the present study, plots of two of the most prominent commercial varieties of Egyptian cotton were grown this year at Yuma, Ariz., from newly imported seed obtained by Mr. David Fairchild, through the kindness of Mr. George P. Foaden, Secretary-General of the Khedivial Agricultural Society of Cairo, Egypt. A study of these plants has enabled us to gain an idea of the range of diversity which the Egyptian cottons are able to show before they have had an opportunity to be hybridized with Upland cottons in the United States. Doubtless these plants are more diverse than the same varieties would be under accustomed conditions in Egypt. A similar increase of diversity is known to take place in Mexican and Central American varieties of cotton when planted for the first time in Texas.

It has not been possible to find any single character in which the newly introduced Jannovitch cotton is uniform and constant. The habit of growth, the form and color of the leaves and flowers, the size and shape of the bolls, the fuzzy coating of the seed, and the length, strength, abundance, and color of the lint are all shown to be capable of pronounced variation.

Some of the plants had fertile branches near the ground, while on others all the lower branches were transformed into sterile "limbs" and produced no bolls or were only beginning to do so at the end of the season, near the top of the plant. The color and texture of the foliage vary considerably, some of the plants having a much lighter and more yellowish shade of green than the others. The lobes of the leaves are much longer and narrower on some plants than on others.

The flowers show a wide range of color. The prevailing tint is a rather deep, almost orange-yellow, though many have a lighter lemon shade and a few are pale and creamy, scarcely darker than those of Upland varieties and with the dark basal spots on the petals faint and broken, much as in hybrids with Upland cottons. And yet these pale-flowered plants showed no other approach to Upland characters.

The bolls vary in size and shape, some being rather short and rounded and others long and pointed and with the sides more or less flattened. The end may be drawn out into a distinct beak or may be abruptly shortened. The surface varies from a very dark blackish green to a much lighter green, more like that of the leaves and bracts. The oil glands which are scattered over the surface of the bolls also vary much in the different plants. Some bolls have very numerous small glands and others larger glands standing farther apart. The number of locks or compartments of the bolls varies from two to five. Two-locked bolls are not uncommon, some being present on nearly every plant. The great majority of the bolls have three locks, many

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of the plants having no bolls with four locks and many only a few. Five-locked bolls were found on one plant, although they were not supposed to occur at all in Egyptian cotton.

Some plants have the seeds almost completely naked, while others have them more than half covered with dense, closely adherent fuzz. The color of the fuzz also varies between a light seal-brown and a rather bright bluish green. Both the brown and the green fuzz may be combined with somewhat more woolly, whitish fuzz, especially at the upper or more rounded end of the seed. Seeds completely covered with white fuzz were also found in the original stock of seed imported from Egypt. These variations of the fuzz are of special interest in view of the fact that Egyptian cotton is sometimes supposed to have only smooth seeds, whereas completely naked seeds are very rarely found.

The lint varies in the different plants as much as any other feature. Not only the length, but the abundance, strength, fineness, and color of the fiber are subject to change. Some of the short lint is less than half the length of the longest; some of the seeds produce only half as much lint as others; some have the very strong lint for which Egyptian cotton is noted, while others have the lint so weak as to be almost worthless. Some have very fine, silky lint, while others have the fiber relatively coarse, coarser, in fact, than some of our Upland cottons. Some plants have lint as white as Upland cotton, while others show the distinctly pale brownish cast which is reckoned as one of the special characteristics of Egyptian cottons.

In addition to these more obvious differences, similar variations may be found in other details. Most of the plants have the calyx completely truncate or with scarcely appreciable, broadly rounded lobes, but some plants have the lobes more distinct and prominent. There is usually a rim of rather sparse hairs above the internal nectary of the calyx, though the hairs are sometimes lacking. The stigmas are usually very long and project far beyond the stamens, but in rare cases the stigmas are short and scarcely emerge from among the stamens, as in some of our Central American types. The stamens also vary considerably in number and arrangement. Instead of the usual compact mass of stamens arranged in five double rows there may be only a few stamens, and these may be widely separated in two groups or bands, one at the end of the staminal tube and the other near the middle, with an open space between. Three plants were found in the block of newly imported Jannovitch cotton which were well outside the range of diversity for the variety in having small white flowers, with petal spots pale or lacking altogether. These plants will be considered later in connection with similar aberrant plants which occurred in imported Mit Afifi cotton.

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DIVERSITY OF NEWLY INTRODUCED MIT AFIFI COTTON.

Newly introduced Mit Afifi cotton, like the Jannovitch, showed a considerable range of diversity at Yuma in 1908, not only in the habits of growth, but more especially in the features of flowers, bolls, and lint. The plants are distinctly shorter on the average than those of the adjacent Jannovitch plot, but the diversity inside the varieties is too great to make it possible to distinguish any other obvious general difference between them. In other words, the characters of most of the Mit Afifi plants are not sufficiently distinctive to separate them from the Jannovitch if the two varieties were mixed together. Nevertheless the diversity of the Mit Afifi cotton seems broader than that of the Jannovitch, so that some of the plants might be recognized by distinctive features not shared with members of the Jannovitch series.

The habits of growth appear less diverse than several other characters. The plants are usually erect and from 6 to 8 feet tall. Some are prostrate, but these have merely broken over by the weight of the limbs and continue growing in a prostrate position. The prostrate plants are as long as those that have remained erect. Growing in the shade of the others the prostrate plants have large, dark green, crumpled leaves with broadly rounded lobes. The leaves of the upright plants have lighter shades of green; they are also more sharply lobed and smaller, with more even surfaces. The widths and lengths of the lobes differ somewhat among the upright plants.

The main axis is not well differentiated from the numerous long, upright basal limbs, which equal it in height. Usually the plants have three or four large limbs that rise from the lowest nodes, but some put out many more, and sometimes from nodes as high as a foot above the soil.

All fruiting branches are, as a rule, borne above the middle of the plant. There is only a slight difference between plants as to the height at which these branches begin to appear. In cases where the fruiting branches are from the lower nodes they are weak growths and retain very few bolls. Bolls retained on the lower branches are also undersized, as if they had been poorly nourished.

All plants agree in being practically devoid of hairs on all their parts. The veins of leaves and of bracts occasionally bear a few short, stellate hairs, but hairiness may be said to be lacking in Mit Afifi cotton.

The bracts differ widely. The usual type is rather long and slender, with short teeth. The three apical teeth grow from a median prolongation of the bract and stand apart from those on either side. The number of the teeth commonly varies from seven to eleven. Bracts can

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be found, however, which depart from all these typical characters. Thus there are broad, coarse bracts with teeth more pronounced and without the usual specialization of the apical teeth. Other bracts have the teeth notably reduced in size and in number. Some of the bracts become red when old or on exposure to the sun, but most of them remain light green.

Three features of Mit Afifi bracts appear to be nearly constant. The mature bracts have a stiff, brittle texture. The young bracts are not so stiff, but are smooth and shining. The second constant feature is the close appression of the bract to the bud and boll. The bracts of Egyptian cottons, unlike those of Upland varieties, have no distinct bulging at the base, no external indication of the place where the bract separates from the enlarged extremity of the peduncle. Instead of being deeply notched at the base, with the corners extending back on either side, as in Upland cotton, the base of the bract is more nearly a straight line, making the general shape of the bract triangular rather than cordate.

The calyx is normally longer than in Upland cotton, and has a nearly even, truncate margin, though variations are frequently met with. The calyx may be considerably shortened or may show broadly rounded and irregular lobes. Sometimes the calyx has a large lobe on one side, while the other side is correspondingly abbreviated. It has been observed by Mr. F. L. Lewton that the calyx of the Egyptian cottons does not fit so closely about the bases of the petals as in the Upland cotton. This permits a large species of carpenter bees to steal nectar from the Egyptian cottons without going inside the flowers.

The internal nectary of the calyx is usually accompanied by a rather indistinct band of hairs along its upper margin. The length and abundance of these hairs differ on different plants, while on a few the hairs are altogether wanting. Upland cottons have a very distinct ring of hairs surmounting the internal nectary, in some cases quite prominent.

The color of the flowers of Mit Afifi cotton is a bright lemon-yellow, with dark reddish purple spots at the base of the petals. Partial abortion or failure of flowers to open is frequent in Mit Afifi plants, though not found in Jannovitch. In the diversity of its flower characters the Mit Afifi cotton shows greater range than the Jannovitch. Few of the flowers are as deep a lemon-yellow as the deepest of the Jannovitch flowers and many are paler than the palest Jannovitch. The pale flowers of the Mit Afifi plants have about the same shade of color as the pale-colored flowers of Upland hybrids. The petal spots show considerable range also, from large or dark spots to small and light. One plant bearing deep yellow flowers had petal spots so

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faint as to be barely distinguishable. The shade of the petals and the depth of the color of the spot are not correlated in any way. The shade of purple in the petal spots is the same in the three imported stocks of Egyptian cotton growing at Yuma.

The petals of the Mit Afifi cotton usually appear somewhat shorter and smaller than those of the Jannovitch. The average length of the petals is about 2 inches, while the range is from 1½ to 2¼ inches. The style may protrude more than half an inch beyond the staminal tube or it may barely extend above the stamens. Stable Upland varieties do not show this irregularity, but as a rule this part of the pistil is consistently short. In Mit Afifi cotton grown for several years in Arizona the style is more uniformly short and thicker than in plants from newly introduced seed. No variation was detected in the color of the Mit Afifi pollen, which is a golden yellow.

One of the most distinctive flower features of Mit Afifi, as well as of Jannovitch cotton, is the arrangement of the stamens in five double series, which is apparent as one looks into the open flower. This appearance is due partly to the short staminal filaments. It occurs also in the Asiatic cottons which have similar short stamens. Opposed rows of stamens rising from each of the five ridges of the staminal tube lean toward each other to form the double series. This is not a constant feature in the Mit Afifi cotton growing at Yuma; some of the flowers have no indication of the arrangement of the stamens, though their stamens may be as short as in other flowers which have the feature well marked. In flowers of Upland cotton, where the filaments are much longer than in Egyptian, this arrangement of the stamens is never apparent.

Perhaps the greatest diversity in the imported Mit Afifi cotton appears in the shapes and sizes of bolls. The most common type is a well-filled boll 1½ inches long by 1 inch in diameter, with a rather blunt point. Some plants bear long, narrow, pointed bolls, while the bluntness of the usual type is occasionally exceeded by the very short, nearly spherical bolls found on some of the plants. The range of these boll characters is greater than in imported Jannovitch cotton, though the Mit Afifi bolls average shorter and thicker than those of the Jannovitch. The bolls are of a dark, shining green and are pitted with large black oil glands which lie close to the surface and deepen the dark green color. In rare cases the bolls are lighter green, with dull surfaces or with the oil glands somewhat more deeply buried under a layer of green tissue.

The predominant number of locks or carpels is three. The most frequent deviation from this is to the two-locked boll. Nine plants out of ten on which a census of the number of bolls and their locks was taken bore two-locked bolls, one plant having as high as 43

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per cent of the two-locked bolls. A few of these had also one or two four-locked bolls, but it seems a general rule that when two-locked bolls are borne in any considerable numbers (15 per cent or more) it is to the exclusion of four-locked bolls, and vice versa. One plant had 33 per cent of four-locked bolls and no two-locked bolls. On the other hand, when the bolls of a plant are nearly all three-locked, both two-locked and four-locked bolls may be found in small numbers. The plant having the high percentage of two-locked bolls grew in the same row and next to the individual with the abundance of four-locked bolls. Diversity in this particular is evidently inherent in the plant rather than dependent upon differences in soil and moisture.

The lint varies to nearly as great an extent as the boll. The usual color is light buff. This is more constantly the case than in Jannovitch cotton, but many shades of buff are found; a few plants have the lint nearly white. The texture also varies from silky to harsh, the latter approaching the short-staple Uplands. The range of length is from 1 inch to 1½ inches, but the majority of plants have staple about 1¼ inches in length. In Upland cottons the fibers on different parts of the seeds are sometimes of different lengths. It is usual to find long fibers at the end of the seed and short fibers at the base, giving the "butterfly" appearance when the lint is combed out on the seed. The Mit Afifi seed may also bear fibers of different lengths, but the long fibers seem usually to come from the middle of the lint-bearing area of the seed and the short fibers from the extremities. The Mit Afifi seeds are never as well covered with lint as seeds of the best Upland cottons, the lower half or third of the seed often having no lint. There is also much difference in the quantity of fiber borne by seeds of different plants. Some have heavily linted seeds, while others have seeds nearly bare. The fibers are also much stronger on some plants than on others.

The seed of the Mit Afifi cotton usually has a tuft of greenish or brownish fuzz at either end, and the tufts are often connected by a line of fuzz along the ridge of the angled side. All degrees are found on the one hand between such seeds and those that are perfectly smooth or nearly so, and on the other hand the fuzz may be more abundant and longer, until a close likeness to the fuzzy Upland seed appears. The rounded surface of the seed, opposite the flat side, is least likely to become fuzzy, especially the portion of it near the base of the seed. Differences also appear in the color of the fuzz, some seeds showing more green than others, but green fuzz is not so noticeable as in Jannovitch seeds, a large proportion of which have bright green fuzz. The range of diversity in seed characters of Mit Afifi cotton grown in Arizona for a single season can hardly be said

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to be greater than in imported seed from which it is grown; the most that can be said is that the quantity of fuzz averages somewhat larger in the seed grown in Arizona.

Of the Mit Afifi seed imported in 1908 about 62 per cent had the usual fuzz tufted at both ends and sometimes extending along the raphe; in most cases the fuzz was green, though greenish brown and brown fuzz also occurred. About 6 per cent was naked or with only a minute trace of fuzz at the base. After the typical seeds and the naked seeds had been taken out the remainder were divided according to differences in the amount of fuzz into "nearly naked," "moderately fuzzy," "almost completely fuzzy," and "completely fuzzy." The first of these classes represented 21 per cent of the general total, and the other three classes, taken together, 11 per cent. Seeds that are completely fuzzy are represented by the smallest percentage—0.16 per cent. All these stages and degrees of fuzziness were found in seeds of otherwise typical shape, size, and color; that is, of a full oval or oval-pointed form, 9 mm. long, weighing 10½ to 11½ grams per 100, and of a uniform chestnut-brown color.

Though apparently independent of the amount of fuzz, many differences of shape, color, and markings could be found among the imported Egyptian seeds. About 25 per cent of all the imported seeds had longitudinal grooves for about one-fourth the distance or less from the base. These grooves were light colored, as if there had been checking of the surface as a result of shrinkage. Between the grooves the surface was black, darker than usual, and with a somewhat charred appearance. In a few cases the whole surface was checked or covered with a rough tissue like charcoal.

Some of the imported seeds were also aberrant in shape, size, or color. Some had very light or very dark seed coats, some were extra large, weighing 14 to 15 grams per 100, which is from 4 to 5 grams more than typical seeds, and others very small and weighing only 5½ to 6½ grams per 100. Long, flat, and round seeds were also selected. The long seeds were 1 mm. longer than the typical and with diameter much less in proportion to length than in typically shaped seeds. The flat seeds resembled apple seeds somewhat in shape and had the raphe along one edge. Blunt seeds, shorter than those of normal shape and for this reason more rounded, were described as "round." Altogether sixteen distinct seed types were selected for separate planting to determine whether any definite correlations exist between the characters of the seeds and the plants they produce.

While a considerable amount of this diversity among seeds has already been recognized in Egypt, it has not yet been found to be correlated with diversities in the plants, though it is evident from the reports of Mr. Balls that diversities are found in Egypt in the

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flowers, bolls, and lint very similar to those that have appeared in Arizona.[a]

ABERRANT TYPES IN IMPORTED JANNOVITCH AND MIT AFIFI COTTONS.

The most extreme forms of diversity in the plantings of imported seed were shown in a few plants that seemed to stand well outside of the general range of diversity of the varieties in which they appeared. Three cases of this kind were studied in the Jannovitch plot and three in the Mit Afifi. While there were notable differences between them, they had also a more general resemblance to each other than to the varieties in which they appeared. The flowers were in all cases of a very light creamy tint, the same as in our United States Upland varieties, and the petal spots were very faint or lacking altogether. The vegetative differences were much less conspicuous and might easily have been overlooked if the pale flowers had not drawn special attention to the plants.

The three Jannovitch plants represented two types. Two of these plants agreed in habits of growth and in flower characters. They displayed a more pronounced tendency toward branching at the base, and the long basal branches were unusually slender. The main axis was no stronger than the branches. The leaves of one plant were small and narrow lobed, while in the other they were large, slightly crumpled, and with broadly rounded lobes, the two extremes of Jannovitch leaves being represented by the two plants. The bolls, though of the usual dark, shining-green color, were unusually small and nearly round. In the number of their locks they did not differ from the other plants in the same block, one bearing 17 two-locked and 178 three-locked bolls, the other 4 two-locked, 170 three-locked, and 3 four-locked bolls. As in the case of the other Jannovitch plants grown from imported seed no fruit was borne below the middle of the plant. The bud and flower characters alone were the distinguishing features.

The bracts were small and quite distinct from Jannovitch cotton in shape and in the distribution of their teeth. They were frequently much broader than long, and with the margins evenly rounded; the teeth were small and uniformly distributed, without the separation of three at the tip of the bract common to Jannovitch cotton. The flowers behaved as though proterogynous, the stigmas protruding from the tip of the half-grown buds. This was due to the incongruous combination of the long Jannovitch pistil with very short petals, the petals being barely half as long as the average for the variety. In the open flowers the petals were about as long as the

[a] Report of the Khedivial Agricultural Society for 1906, pp. 49 and 65.

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bracts and the stigma often extended beyond both, a very infrequent condition in cotton flowers.

On one plant the flowers had no petal spots and on the other the spots were barely apparent in some of the flowers. Such correlation of light petals and faint petal spots have been known to occur only in cases of hybrids; the palest flowers of normal Jannovitch cotton have petal spots as dark as those with darker petals. Nevertheless, there was no indication that this plant was a hybrid with an American Upland cotton. The usual correlation of characters common to Egyptian-Upland hybrid flowers—bell-shaped white flowers with sharply lobed calyx and long stamens with light-colored pollen—did not occur in this white-flowered Egyptian plant. The pollen was as yellow as in typical Jannovitch cotton and the stamens were even shorter than usual for this variety.

The lint of one plant was nearly white, while that of the other was light buff. In both cases it was of good length and quality and of medium strength, the buff lint being stronger than the white. On the plant bearing white lint, only one or two seeds developed in a lock. Furthermore, these seeds sometimes failed to turn black.

The third of the diverse Jannovitch plants, representing the second type, was like the other two in approximating the Egyptian style of growth and foliage. The limbs were more spreading than usual and the leaves lighter green. In other respects it differed as widely from the other white-flowered Jannovitch as from the normal Jannovitch cotton. The bracts were of stiff Jannovitch texture, but were broad and cordate. The flower was about the size of the normal Jannovitch flower, but pale, with pale red spots. The calyx was sharply lobed, one or two or the lobes being greatly elongated. The internal nectary bore a distinct band of long, abundant hairs. The bolls were light green, larger than Jannovitch bolls, round, with a prolonged beak. Of the bolls 74 were four-locked, 23 three-locked, and 7 five-locked. The lint was tinged with buff and was abundant, short, and silky. The seeds were more nearly round than in normal Jannovitch cotton, and even larger than in American Upland varieties. Many of them were about two-thirds covered with a dense, green fuzz. Others were not so fuzzy, but all bore more fuzz than is usual for Jannovitch cotton. The naked surfaces of the seeds were black and irregularly pitted.

The three aberrant white-flowered plants in the block of newly introduced Mit Afifi cotton resembled the two already described as the first type in Jannovitch. In all but flower and boll characters these plants were indistinguishable from the normal Mit Afifi cotton. The flowers were white in all three cases and had no petal spots. The petals were much smaller than the average for Mit Afifi. The flowers

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differed from those of the similar type in Jannovitch plants in not being proterogynous. Though the petals were short the pistil was likewise abbreviated; even in the open flower the pistil did not extend beyond the petals as in Jannovitch cotton. Differences only slightly marked in normal plants of the two varieties were accentuated in these white-flowered types. In all the white-flowered Mit Afifi plants the style protruded but slightly beyond the stamens, while in the Jannovitch plants the corresponding portion of the style was very long. The staminal tube of the white-flowered Mit Afifi plants was constantly longer than in the Jannovitch cotton. This accounted to some degree for the shorter extension of the style beyond the staminal tube in the Mit Afifi cotton, though the style is absolutely shorter in this variety than in Jannovitch. The point of origin of the staminal zone was higher above the base of the flower in Mit Afifi, and the zone itself was longer than in Jannovitch cotton.

The white-flowered Mit Afifi plants differed further from the two similarly aberrant Jannovitch plants in having a faint hairy rim above the internal nectary of the calyx. There was also a much larger percentage of four-locked bolls than in the aberrant Jannovitch plants, and two of the three plants bore a few five-locked bolls. The shapes of the bolls of the white-flowered Mit Afifi plants were diverse, varying from round to blunt-oval. There were also differences in size, the largest being $1\frac{5}{8}$ inches long by $1\frac{1}{8}$ inches in diameter. On one plant the bolls were light green and lacked the shining smoothness of surface usual in Mit Afifi cotton. Similar diversities in boll characters did not appear among the white-flowered Jannovitch plants.

One of the three Mit Afifi plants showed great degeneracy. Very little fruit had been retained, though the flowers were produced in normal abundance. The few bolls that reached maturity had sunken carpels and only one or two poorly linted seeds.

HYBRID NATURE OF THE ABERRANT JANNOVITCH AND MIT AFIFI PLANTS.

In some particulars the white-flowered Mit Afifi type is intermediate between the two Jannovitch types. In style of growth and in flower characters the white-flowered Mit Afifi plants are close counterparts of the first of the white-flowered Jannovitch types, except that they bear five-locked bolls like the second Jannovitch type. Their resemblance to the first type in Jannovitch is so marked that a similar foreign influence is naturally to be suspected.

But if hybridization is responsible for the diversity it also seems probable that the cross is of long standing. The preponderance of the Egyptian characters is large and the lint averages the same as that of normal plants except in a single individual. Two of the

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white-flowered plants in the Jannovitch plots and the three in Mit Afifi differ less among themselves than do many of the normal plants of these varieties. Furthermore, indistinct varietal characters of normal plants are consistently accentuated and made prominent features of the aberrant plants, as often occurs in hybrids.

The combinations of characters found in the Jannovitch plant that gave the strongest indications of hybridity differ sufficiently from those observed in the known Egyptian-Upland crosses to make it reasonably certain that the source of contamination was not American Upland cotton, but seem to indicate that the foreign parent resembles Upland to some extent. The correlations of flower characters are the same as those that appear very frequently in the Egyptian-Upland hybrids. The petals are white, the petal spots faint, the calyx lobes pronounced, and there is a distinct hairy rim above the internal nectary.

The accentuation of the lobes of the calyx to such an extent as in one of the suspected Jannovitch hybrids finds no counterpart in the several generations of Egyptian-Upland hybrids which have been studied, and this plant also bears five-locked bolls with large, green-fuzzy seeds and short lint. The peculiar rounded shape of the seeds and their large size and partly naked, rough surface do not correspond with anything found among plants known to be Egyptian-Upland hybrids.

Considering the white-flowered Egyptian plants as hybrids, the most probable source of infection seems to be the "Hindi" cotton, an inferior, white-linted type not now planted in Egypt, but which persists as a weed and mixes with the Egyptian cotton to the great detriment of the fiber, as several investigators have reported. The Hindi cotton has white flowers without petal spots, and five-locked bolls, characters which in the plantings of newly imported Egyptian cottons at Yuma were peculiar to the aberrant plants alone. At the same time these plants do not have seeds like the Hindi cotton, which are said to be long, narrow, and free from fuzz, and thus easily recognized. A considerable effort has been made by the Khedivial Agricultural Society, of Cairo, to eliminate the Hindi plants by culling out the seeds from the commercial varieties, Mit Afifi in particular. Even in the best samples there is said to be an admixture of 2 or 3 per cent of Hindi seed.[a]

This precaution has not been found adequate to eliminate all the plants with Hindi characteristics, which makes it evident that the

[a] Foaden, George P., secretary-general of the Khedivial Agricultural Society. "The Selection of Cotton Seed," in Yearbook of Khedivial Agricultural Society for 1905.

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Hindi peculiarities of the seed are not always obvious. This has also been appreciated in Egypt, as the following statement[a] will show:

> Finally, I may say that even in fields which have been picked free from Hindi, both on the seed tables and at thinning out, I have this year found a large percentage of plants bearing one or more inconspicuous Hindi peculiarities shuffled into the pack of Afifi characteristics.

It is evident from this statement that the only method of keeping the undesirable Hindi characteristics in abeyance is to maintain a still more efficient selection, based on more general knowledge of the characters that enable the Hindi hybrids to be detected.

MIT AFIFI COTTON MORE DIVERSE THAN JANNOVITCH.

While the plots of newly introduced Jannovitch and Mit Afifi cottons at Yuma fall far short of the standards of uniformity usually applied to Upland varieties, it seems that Jannovitch cotton approaches this standard more nearly than does the Mit Afifi. The flowers of Jannovitch plants are darker yellow and show less variation of color than do the flowers of Mit Afifi. The basal spots of the petals likewise are nearly always large and dark in Jannovitch plants, while in Mit Afifi there is more variation and all degrees from very dark to very pale spots. The portion of the pistil extending beyond the staminal tube is longer and more constant in length in the Jannovitch cotton. Only a few plants are found with the pistils abbreviated, a condition of rather frequent occurrence in Mit Afifi. The Jannovitch cotton also has a more regular form of boll, long and pointed, about $1\frac{5}{8}$ inches in length by 1 inch in diameter. Blunt bolls are sometimes found, but the range of diversity is not so wide as in Mit Afifi. Here the usual shape is rather blunt, with an abrupt, short point, but some of the Mit Afifi bolls are even more pointed and narrower than those of the Jannovitch cotton.

DIVERSITY IN THE DALE EGYPTIAN COTTON.

A third type of Egyptian cotton planted at Yuma was the Dale, a variety of unknown ancestry only recently brought forward in Egypt and now planted for the first time in America.[b] It differs from both the Jannovitch and the Mit Afifi varieties in peculiarities of its vegetative characters and habits of growth, quite as marked as the vege-

[a] Balls, W. Lawrence. "Seed Selection," in Yearbook of the Khedivial Agricultural Society for 1906, p. 81.

[b] Grown from seed sent to the Department of Agriculture by Mr. Alfred Dale, Mansurah, Egypt, with the following remark: "A special quality I have cultivated on my farm for the past year, which has given splendid results both in quality and quantity."

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tative characters that distinguish Upland varieties. The range of diversity is also much greater than in the other Egyptian varieties, and in some respects is fully as great as would be expected in a series of hybrids.

Many of the plants have abnormally short fruiting branches like the "cluster" varieties of the Upland type. The bolls are often borne on very long peduncles and in clusters of three to six, or even more. The plants which bear their bolls in this manner are tall and spike-like, with coarse, dark foliage, characters also frequent in Upland cluster cottons. Other tall plants bear their bolls only at the ends of the branches, but not in clusters. Still other plants, including the tallest of all, are completely sterile. All the tall plants have long basal limbs, but the main axis is always strongly developed. A fourth style of plant is more nearly like the Upland, with normal fertile secondaries and bearing some of the fruit below the middle of the plant. This type of plant also resembles the Upland in bearing five-locked bolls. Indeed, it appears that five-locked bolls are of more frequent occurrence in the Dale type than are two-locked bolls, though plants bearing two-locked bolls also occur. The two-locked bolls were found on two small plants of a type rather aberrant in other respects. One of them had perfectly smooth seeds and very sparse, weak lint. The majority of the plants bear three-locked and four-locked bolls, the three-locked bolls being predominant. The locks were counted in the bolls of twelve plants and the percentage of four-locked bolls was about 15.

The range of diversity in the size and shape of bolls is much greater than in the other Egyptian varieties, and this is true also of flower characters. Large and small flowers, lemon and cream colored petals, and dark and pale petal spots are all represented in the planting. Even in the same flower the petal spots may range from dark to very faint on the various petals.

The bracts do not resemble those of the other Egyptian cottons, but are broad (some broader than long), more strongly laciniate, with the laciniæ longer and broader than in Jannovitch or Mit Afifi cotton and without the Egyptian arrangement of three laciniæ at the apex of the bract. There is also a notable frequency of abnormal bracts intermediate in form between ordinary leaves and fully specialized bracts. This series of abnormalities has a botanical interest in affording apparently conclusive evidence of the nature of the modifications that have been made in specializing leaves into bracts. The stipules become greatly enlarged, the blade correspondingly reduced, and the petiole eliminated entirely. The three large teeth in the middle of the bract represent the lobes of the leaf, the other teeth being borne

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on the enlarged stipules. The nectary at the base of the bract corresponds to the nectary on the midrib of a normal leaf.

DIVERSITY IN LATER GENERATIONS OF MIT AFIFI COTTON.

Experiments with recently introduced Central American types of cotton have made us familiar with the fact that an even greater amount of diversity is often shown in the second and third generations than in the first, depending upon the extent to which the characters of the variety are disturbed by the transfer to new conditions.

That the total diversity should be greater in the second generation of a stock than in the first generation is easily to be understood from the fact that the seeds which produce the second generation must develop under the new conditions, whereas those which produce the first generation have been developed under conditions normal for the variety. A variation that takes place in a seed or a seedling is to be compared with the variation of a bud or branch rather than with the variations that occur when new conjugations take place.

That new conditions are even more likely to disturb the processes of heredity at the time of seed formation than during the previous period of vegetative growth is shown by the many instances of carefully selected varieties of vegetables and flowers which will produce one generation of normal plants under new conditions, but show marked diversity and deterioration in the second generation. Some of Mr. Kearney's special selections from individual plants have attained a uniformity notably greater than that of the new plantings of the Egyptian varieties, but in the bulk plantings, and especially in plantings made under conditions different from those in which the original breeding was done, a wide range of diversity is still to be found, in some respects even wider than in the plats raised from the newly imported seed. Nevertheless, it does not appear that this persistence of diversity is in the nature of a failure of acclimatization or that it indicates any special resistance to acclimatization on the part of this type of cotton.

The effect of the selection thus far applied can be fairly judged only by the selected stocks themselves, which are often very uniform. Apart from hybrids the diversity of the bulk plantings is largely explained by the diversity between the various selections whose seeds were combined in the bulk plantings. Considerable diversity could be ascribed very properly to the mixture of the seed of the different selections and the crossing of the selections among themselves. Indeed, it is a more difficult problem to explain the uniformity of the selections, unless we consider that some of them represent mutative variations which are sometimes notably prepotent and constant in

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their progeny even when freely exposed to crossing with the parent form.

The fact that the Arizona-Egyptian plants were grown in large numbers and in several different localities under different conditions would also tend to increase the impression of diversity by giving more numerous opportunities for differences to appear. Finally, the presence of numerous and diverse Upland hybrids would itself tend strongly to establish an impression of diversity, even if the Egyptian plants themselves were more nearly alike than they are.

Differences in fertility, rather than in other special characteristics, is the most serious form of diversity and that which shows most definitely that acclimatization is still incomplete. Inequalities in the yield and the quality of the lint are frequently out of all proportion to any differences of natural conditions reflected in the stature or apparent vigor of the plants. This form of diversity was found to depend on the fact that the cotton plant bears two distinctly specialized kinds of branches, one fertile and the other sterile, as will be explained in later chapters.

DIVERSITY AFFECTED BY METHODS OF BREEDING.

The practical work of acclimatizing a foreign variety like the Egyptian cotton consists simply in the selection in each season of those plants that behave in a normal manner or in a manner which most nearly approaches the normal. The primary object of acclimatization is not to change or improve the variety, for which selection is often used in other cases, but to preserve the variety and rescue it from the agricultural deterioration which results from too great and indiscriminate diversity. Instead of attempting to bring about changes of characters our efforts are directed toward securing greater stability in the expression of the characters.

Even without any special selection there is often a distinct tendency to return toward the normal adjustments. Even when the first generation of a newly introduced cotton is nearly sterile each succeeding generation tends to be more fertile and productive. Nevertheless, it is hardly to be expected that there would be any complete return of the variety to its normal characters without the assistance of selection. The diversity which the new conditions arouse may be thought of as representing the same diversity that was suppressed when the variety was originated by selection. The new conditions having disturbed the adjustments and released the old diversity, a new selection is required to restore the previous uniformity, that is, to

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separate again the lines of descent that have the strongest tendency to express the desired set of characters.

The process of acclimatization in the strict sense would be finished when the variety had been restored to a condition of stability, so that crops as normal and uniform as those of other varieties that are being planted in the same region could be raised. This has been accomplished in Texas with several strains selected from Central American stocks introduced four years ago.

The diversity aroused by the new conditions is likely to afford novelties which attract the interest of the breeder and furnish him very promising material for the development of valuable new types. Some of Mr. Kearney's best selections show vegetative characters quite different from the average form of the Egyptian plants and apparently quite superior. At the same time it has to be considered that the behavior of these new types may not be quite the same as if the normal, typical form of the parent variety had been retained. Among the Central American varieties at least, those strains seem to be most promptly acclimatized which are nearest to the ordinary form of the parent stock as it grew in Central America. Selections of such individuals often yield a very uniform progeny, whereas selections of other types continue to show a larger amount of diversity. Such instability may be compared to the instability of hybrids, in that the forms secured in this way represent new combinations of characters, or at least unaccustomed combinations. It is easy to understand that such new combinations may be less stable and less promptly reduced to uniformity than combinations that have been expressed with regularity for many generations.

Not only is there a distinction to be drawn between acclimatization and breeding, but a practical difference of methods may need to be used, at least in the case of cotton. If selections were kept inside of the varietal type and had only the minor fluctuating differences in degrees of fertility or lengths of lint, crossing between these selections might have no serious effect in retarding acclimatization. But where each selection is likely to represent a diversity equivalent to a distinct variety, the crossing of such selections may prolong the condition of instability, if it does not have a further tendency toward a deterioration or mongrelizing of the type. Free crossing among numerous varieties of the same species often leads the composite group back to the characters of the wild type and may produce a serious deterioration, particularly when the characters of the varieties represent the results of special selection.

The bearing of these facts upon the problem of acclimatizing the Egyptian cotton is not difficult to understand. To secure the most

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rapid progress of the work of acclimatization it ought to be considered as entirely distinct from the work of securing improved types of Egyptian cotton. The selections for these two purposes should be conducted on separate lines and by different methods. The diverse forms, whether superior or not, should be removed from the stock that is being acclimatized. The normal form and habits of growth, combined with the normal fertility and the lint characters, should constitute the standards of selection, if prompt acclimatization and attainment of commercial uniformity are the principal objects. The development, testing, and substitution of new and improved types may be considered as representing a later stage in the development of an established industry. Even though distinct improvements can be made later on, it is likely to be an advantage to begin with the nearest possible approach to methods already tried and to products already in demand.

RELATION BETWEEN DIVERSITY AND EXTERNAL CONDITIONS.

It is a most familiar fact that plants of the same kind will show different characteristics when grown under different conditions. This power of the plants to adapt themselves to different conditions is very important in an agricultural species or variety if it is not to be restricted to one locality or set of conditions. Cotton is one of the most adaptable of plants, able to thrive and produce an abundance of seed under a very wide range of natural conditions, and able to make notable changes of form and habits of growth in accord with the needs of many different surroundings.

Nevertheless, this readiness of adaptability is not without its disadvantages, especially in such a plant as Egyptian cotton, where the uniformity of the product is quite as important as the amount of the yield. In changing the characters which have to be varied for the sake of adaptation to different external conditions, other characters are likely to be changed or to fall out of adjustment. Each fully developed plant represents a balanced combination of many characters.

Selection is our means of compelling a variety to repeat the particular combination of characters that we desire, but the adjustments established by the selective breeding of a variety under one set of conditions are often lost or diminished when the plants are transferred to a new set of conditions. Though new conditions may be equally favorable, or even more favorable, the close adjustment of the varietal characters are likely to be disturbed whenever there are

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any changes or substitution among the characters which are affected by the external conditions. Even when a variety continues to be grown in the same place, seasonal differences of temperature and rainfall are often sufficient to disturb the adjustments of the characters, so that different years may bring great differences in the uniformity of the same crop.

The experiments with the Egyptian cotton at Yuma and at Sacaton may be viewed as an example of such a loss of adjustments. The natural conditions at Sacaton did not appear to be less favorable than at Yuma as far as they could be judged by the size and productiveness of the plants, nor did the total amount of diversity among the plants appear to be greater at Sacaton than at Yuma. Nevertheless, the effects of the selection for long lint which have been made at Yuma were notably less apparent at Sacaton. Very few plants, if any, showed as long lint as many of the better selections at Yuma. Most of the Yuma plantings had the advantage of an additional year of selection, which might have been expected to have a favorable effect upon the average of the lint, but can hardly be thought to explain the almost complete failure of even individual plants at Sacaton to attain the Yuma standards. Further experiments must determine, of course, the extent to which this difference represents a phenomenon of acclimatization. It is possible that the Sacaton conditions may be less favorable to long fiber than those at Yuma, but the general behavior of the plants does not lead us to expect any permanent difference of this kind.

This relative inferiority of the Egyptian lint at Sacaton made the hybrids appear more definitely superior to the pure Egyptians than at Yuma, though there was no indication that the Sacaton hybrids were really better than the Yuma hybrids. They seemed in fact to be not quite as good, and yet they gave a stronger impression of superiority over the pure Egyptians.

In this particular case the transfer of the plants to new conditions appeared to shorten the range of diversity rather than to increase it, there being less of the long lint shown at Yuma. But if acclimatization had been complete at Yuma, so that the long lint had become a more uniform character, the transfer to Sacaton would doubtless have caused the diversity to appear greater by allowing many of the plants to fall back to the short lint, after short lint had ceased to appear at Yuma.

IMPORTANCE OF HABITS OF BRANCHING.

The most marked effects of different conditions of growth are exerted through their influence upon the methods of branching. The

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branches of the cotton plant are of two definitely different forms.[a] Fertile branches are horizontal or drooping. Each joint bears a fruit bud, and the internodes are twisted to bring the buds to the upper side. Sterile branches, or "limbs," are upright or ascending, with long straight joints and no fruit buds. The sterile limbs are to be thought of as subdivisions of the main stalk and have the same function. Like the main stalk they can produce other branches which are fertile, but are themselves unable to set any flowers or fruits. If all of the lower branches are of the sterile, upright form the flower buds can not begin to form till the second generation of branches has been put forth. This delay contributes to the lateness of the crop, which is usually reckoned as a characteristic of the Egyptian type of cotton.

Nevertheless it appears that in Arizona, at least, heavy yields depend largely upon the size of the contribution made by the fertile branches formed on the main stem within 2 or 3 feet from the ground. The plants seldom attain any satisfactory degree of fertility unless they begin by putting forth many of the short horizontal fruiting branches from the lower part of the main stem. Reference to Plates I and II will enable the reader to gain an idea of the intimate relation between fertility and forms of branching.

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[a] In view of the practical importance of recognizing the two distinct kinds of branches, it may be well to add a summary of facts stated in a former publication. (Weevil-Resisting Adaptations of the Cotton Plant, Bulletin 88, Bureau of Plant Industry, pp. 19 and 20.)

Two buds are formed at the base of each leaf of a cotton plant. The bud that comes from the middle of the base or true axil of the leaf grows into a vegetative branch, never into a fruiting branch. These vegetative, axillary, or primary branches are like the main stem in that they produce fruiting branches, but they never produce directly any flower buds or bolls. The fruiting branches, as well as the flower buds they bear, arise in an extra-axillary position at the right or the left side of the true axillary bud. Thus each cotton stalk or vegetative branch is either right-handed or left-handed with respect to the arrangement of the fertile branches, conforming to the direction of the spiral in which the leaves are inserted.

External conditions may affect the development of the branches in two principal ways—by inducing the formation of an abnormal number of primary branches or by leading the secondary branches to behave like primary branches. Although axillary buds do not produce fruiting branches the extra-axillary branches often assume the form and behavior of vegetative branches. It is the regular habit of some types of cotton to keep the axillary buds in a dormant condition and to form vegetative branches by vegetative transformation of fruiting branches. After this change takes place there is no return to the fertile form. A branch that begins to grow without producing flower buds on the basal internodes never produces any flower buds. Unless branches of the fruiting type are formed no flower buds can be put forth and the plant remains completely sterile, no matter how large and luxuriant it may be. (*O. F. C.*)

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If the plants have too strong a tendency to vegetative growth early in the season too many of the branches take on the sterile form. (Pl. I, fig. 2.) The plant may then fail to develop any of the lower fruiting branches or may leave them small and stunted. (Pl. I, fig. 1.) And even after a promising development of the fruiting branches has taken place and goodly numbers of bolls have been set, they may fail to attain a normal growth if the plant falls later on into the condition of too great vegetative luxuriance. Not only is there a cessation in the formation of more bolls, but even those that are already formed may shrivel and drop off, or may be able to form only abnormally short and weak lint. This direct evidence of the change of the plant's activity from the reproductive to the vegetative side is very common. Sometimes all the bolls of the lower part of the plant are inferior, and sometimes the lowest are notably better than those farther up, which could not have been so far advanced when the change of tendencies took place.

The unusual liability to change greatly intensifies the influence of the external conditions in determining the fate of the individual plants. A plant whose characters are more stable may resist all the influences that upset its less stable neighbors, which may yield to the disturbing influences at different stages of development, depending upon their different degrees of adjustment.

The fact that so many of the plants show normal tendencies of growth in the early part of the season indicates that high temperature is one of the decisive factors, but it is evident that conditions of soil and water supply are often very important in assisting or hindering the change. Rich soil and abundant water predispose the plants to greater luxuriance, while poorer and drier soils tend to hold them back, and thus favor greater uniformity. In the drier parts of the fields at Yuma all the plants (even including the hybrids) appear much more alike than where moisture is abundant. Thus it is probably an aid to acclimatization to keep the plants as far as possible under moderate conditions, to avoid an unnecessary intensification of the instability, and yet to allow the unstable plants to show themselves and be weeded out.

It might be argued that selection will be more efficient if the plants are placed under extreme conditions, so that their powers of maintaining the normal adjustments of their characters may be tested more thoroughly. The danger is that all of the plants may be changed beyond the range of normal behavior, and that this may increase the difficulty of bringing even the best selections back to a condition of practical uniformity. When the changes are too great and too general it also becomes more difficult to tell whether some plants are more normal than others. The plants that prove to be the most fertile in

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the first seasons, when the work of acclimatization is carried on under extreme conditions, do not necessarily represent the best types for agricultural purposes.

The fact that the condition of the Egyptian cotton, with reference to fertility and acclimatization, can be determined from the way in which the branches develop in the early part of the season shows that this feature is of great practical importance. And after acclimatization has been accomplished the development of the fertile branches will be the chief issue with the farmer. Their behavior, more than anything else, will influence the choice of methods of culture as well as the times of planting and irrigation. It is already apparent that the application of too much water at the wrong time may not only diminish the crop but may actually injure the growing bolls.

Though writers on the behavior of Egyptian cotton in Egypt do not seem to have recognized the different types of branches and their relation to external conditions, they have not failed to report that too much vegetative vigor has an adverse effect upon the crop.

> It is noticeable that, speaking generally, the best lint from the cotton grader's standpoint is not produced by the largest and strongest plants, so that in popular expression "running to wood" is objectionable. * * * The provinces of Menoufieh and Gharbieh produce the best cotton in the country, though the climate is less suited to mere growth of the trees than in those provinces which lie farther south. * * * A similar result, though the operating cause is apparently different, is obtained by the "Sea Island cotton" growers in America, who apply salt marsh mud to their crops. This apparently acts by checking root absorption and consequently growth.[a]

Further indications of the methods used in Egypt to hold the vegetative growth in check and induce earlier fruiting have already appeared in a bulletin of this Bureau.

> There has been during recent years a distinct tendency toward early planting, it being contended that during a series of years the largest yields, as well as the best qualities, are produced by early planters.
>
> Early-planted cotton grows more regularly and evenly and does not tend to produce such coarse growth (weed) as that planted later. It also branches better from the bottom.
>
> It is generally accepted that as long an interval as is consistent with the health of the plant should elapse before the first watering is given; otherwise the plant is not encouraged to root well, but tends to grow too rapidly. Too frequent waterings during the early growing period prevent the proper branching of the plants from the bottom. They grow too rapidly, producing their forms at the top rather than from the bottom, and are spindling.
>
> The basis of the mixture of chemical manures employed is superphosphate. * * * It checks the tendency to coarse growth and thus encourages ripening, while it greatly improves the quality of the fiber.

[a] Balls, W. Lawrence. Yearbook of the Khedivial Agricultural Society for 1906, pp. 38–39.

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The use of fresh stable manure causes rank growth, late maturity, and an inferior fiber.[a]

The same difficulties have been recognized among the planters of Sea Island cotton, and the measures of prevention used by them have been noticed in another publication of this Bureau.

This ridge system gives better results in two classes of cases, as follows: * * * (2) When, on account of the land being rich and well fertilized, Sea Island cotton grows too much to weed under level culture. In such cases the grower is compelled to adopt measures to turn the energies of the plant from vegetative growth to fruiting. This is done by restricting the root development, (1) by maintaining a compact subsoil, which the Sea Island planters accomplish in their deep, sandy soils by pasturing with cattle during the year of rest; (2) by regulating the moisture supply by the high beds; and (3) by root pruning by deep cultivation if the cotton needs it.

It is advised that planting be begun as early as the season permits. This varies in different years and sections from March 15 to April 10. Early-planted Sea Island cotton is found to make a more compact and fruitful plant, while late cotton tends to form a larger and coarser weed.[b]

DIVERSITY AFFECTED BY DIFFERENCES OF LOCAL CONDITIONS.

From indications already given regarding the nature of the diversity of the newly introduced varieties it is easy to understand that they are especially susceptible to the influence of adverse conditions. Inequalities of soil or water supply which would affect thoroughly acclimatized varieties only to the extent of making the plants a little larger or smaller may disturb the adjustments of other characters in a partially acclimatized stock and bring about serious deterioration.

Many striking illustrations of this were found at Sacaton, where series of good and fertile plants would often be succeeded in the same row by considerable numbers of others which were notably inferior and unproductive. The definite groupings of the good and bad plants made it evident that something in the soil or water supply must have been the exciting cause of these differences. The inequality might have been extremely slight and temporary, but it was evidently sufficient to start the plants on different courses of development. That the change so generally affects the quality of the lint is not surprising if we consider the fact that the long lint of the Egyptian cotton is a highly specialized character likely to be affected by any disturbance of the process of development, whether by external conditions or by other forms of variation.

[a] Foaden, George P. Notes on Egyptian Agriculture, Bulletin 62, Bureau of Plant Industry, U. S. Department of Agriculture, 1904, pp. 22–24, 28.

[b] Orton, W. A. "Sea Island Cotton: Its Culture, Improvement, and Diseases," Farmers' Bulletin 302, U. S. Department of Agriculture, pp. 24 and 25.

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That otherwise imperceptible differences of conditions in the same fields have been able to exert such notable effects upon the cotton plants affords additional testimony to the fact of instability. It appears more reasonable to believe that the general shortening of the lint at Sacaton may be largely due to the change from Yuma to Sacaton rather than to any directly unfavorable factor in the natural conditions at Sacaton that will prevent the production of longer lint in future years.

A similar deterioration has been observed in Texas, even in the standard varieties of Upland cotton, when carried to different localities. Thus the Triumph cotton bred by Alexander Mebane at Lockhart, Tex., showed notably greater diversity and a lower average in lint when first taken to a higher elevation at Kerrville, Tex. That this deterioration represented the result of the change of conditions rather than of essentially unfavorable conditions was shown by experiments made at the same time and place with plants of the same stock, but raised from seed of normal plants grown at Kerrville in the previous year. The second generation plants were notably superior to those raised from the new Lockhart seed. In a series of such experiments the differences in yields ran between 10 and 20 per cent in favor of the second plantings of the same stocks over first plantings. The improvement in the quality of the lint was even greater.

DIVERSITY IN EGYPTIAN-UPLAND HYBRIDS.

To judge of the degree of acclimatization that has been attained as evidenced by the present extent of diversity in the Egyptian cotton is rendered much more difficult by the presence in the fields of many hybrids between the Egyptian cottons and various Upland varieties. These hybrids not only afford endless gradations and combinations of the parental characters, but the characters are often exaggerated in the hybrids and carried beyond the extremes of the parental types. Primitive characters not commonly represented in the parent stocks may also be brought back to expression in the hybrids.

Instead of being intermediate in size between the large Egyptian and smaller Upland plants the hybrid plants are usually much larger than the Egyptian. The seeds of the hybrid may be larger than those of either parent and they may be more fuzzy than the Upland parent or more completely naked than those of the Egyptian. The most important feature of all, the lint, does not obey the customary rule of intermediate expression of parental characters. Instead of the long Egyptian lint being shortened by combining with the short-linted Uplands there is usually a definite increase in length and strength, especially in the first and second generations. This supe-

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riority of the fiber of the hybrids was readily appreciable in the general field plantings, especially at Sacaton, but was less pronounced in the specially selected stocks at Yuma.

The notable superiority of the lint of hybrids over that of pure Egyptian plants is one of the most interesting facts established by the present study of diversity. Together with the problem of learning how to prevent and eradicate the hybrids, we have also to consider the still more interesting and important possibility of learning whether superior hybrids can not be grown in regular commercial quantities and utilized as a practical means of producing cotton of very high quality.

FREQUENCY OF CROSS-FERTILIZATION.

The experiments with Egyptian cotton in Arizona confirm the results of our Texas experiments in showing that cross-fertilization takes place in a much larger proportion of cases than previous writers on the subject have supposed. The large, showy, open flowers of the cotton plant invite the visits of insects, so that a large amount of cross-fertilization has to be expected whenever different varieties or types of cotton are grown in the same vicinity close enough together for the same bees to visit the flowers of more than one kind.

As the amount of cross-fertilization depends entirely on the number and activity of the bees or other insects that visit the flowers different localities might be expected to differ greatly in the amount of cross-fertilization, and even the same locality in different parts of the season. Thus at the time of our visits to the fields at Yuma and Sacaton there was a notable difference in the activity of the insects at the two places. Several species of large wild bees that were industriously visiting the flowers at Yuma in September were not seen at all at Sacaton.

The fact that cotton flowers readily set seed from their own pollen has led several writers to suppose that cross-fertilization takes place only rarely, but the fact seems to be that foreign pollen is very often brought to the stigmas by the bees before the pollen of the same flower can reach them. This is particularly true of the Egyptian cotton, where the long styles carry the stigmas well up beyond the reach of the short stamens. In Upland varieties which have the stigmas shorter and the stamens longer the opening of the anthers brings the pollen against the stigmas without external assistance, but a long-styled Egyptian flower might remain unfertilized unless visited by insects. The pollen grains of the cotton plant are too large to float about in the wind and also have their surfaces moist and sticky. At

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the same time they are covered with spines which keep them from adhering too closely to each other and yet help to hold them on the hairs of the bees, as well as on those that cover the stigmas.

The idea that cross-pollination is not frequent has probably been strengthened by the fact that hybrids are easily overlooked in experiments where only Upland varieties are being planted. This is because many of the hybrids have a rather close resemblance to one or the other of the parents or are merely intermediate between them. No such range of diversity appears as when two widely different types of cotton are crossed. Hybrids between the two related Upland varieties are generally much less different from the parents than the diversities that arise in the parent varieties without hybridization. And since the usual effect of hybridizing similar varieties of Upland cotton is to shorten the lint, many such hybrids may be thrown out in the process of selection without their true nature being recognized.

When Upland cotton is hybridized by an Egyptian or Sea Island variety the lint does not deteriorate in the first generation, as compared with the long-stapled parent and the hybrid character of the plant usually becomes obvious at once by reason of its greatly increased stature, which equals or exceeds that of the Egyptian parent. The large size naturally draws attention to the many other features of the Egyptian cotton which are predominant in hybrids with Uplands. This predominance of the Egyptian characters, which makes it so easy to detect Egyptian hybrids in Upland varieties, has the opposite effect of increasing the difficulty of recognizing all the plants of Upland parentage in a field of Egyptian cotton. In the first generation it is still very easy to distinguish them in the great majority of cases. In spite of the general resemblance to the Egyptian parent in stature and habit of growth there are many unmistakable features which enable nearly all of the hybrids to be detected without difficulty; but there are others which only those who have made a special study of the subject can hope to recognize, and some in which the most careful inspection has failed to detect any certain indication of a mixed parentage even when known to exist. If only the first generation of the hybrids had to be feared it is possible that the purity of a variety might be safely guarded, but when hybrids have been diluted for several generations of crossing back upon one of the parental stocks it becomes well-nigh impossible to separate them.

Even the most skillful selection can not eliminate hybrids from a cotton variety unless they are taken out before they begin to blossom. Rejection of the seed of the hybrid plants does not dispose of the other seeds borne by other plants which have been fertilized by the

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hybrid pollen. And even though the plants raised from these seeds should again be rejected, the process of forming hybrids may still continue. The foreign blood would become more attenuate, of course, with each generation and the hybrids would more and more resemble the pure stock.

Many plants in the Egyptian experiments show such slight and indefinite departures from the Egyptian type that it is often very difficult to settle upon the non-Egyptian characteristics of particular individuals. But when the abundance of these doubtful cases is taken into account it becomes in itself a sufficient evidence of the fact of hybridity, when a planting is considered as a whole. The objection to these dilute or doubtful hybrids is not alone that they are likely to produce a slightly different lint, which lessens the uniformity of the commercial product, but that they are likely in later generations to give rise to distinctly degenerate plants, which will show some obvious hybrid character and a marked deterioration of lint.

DISTINCTIVE CHARACTERS OF HYBRIDS.

The facts already stated regarding hybrids show that it will always be necessary to guard against hybridization and to recognize it at once if it occurs accidentally, in order to prevent its extension in districts where Egyptian cotton is being grown. The farmer who grows Egyptian cotton, as well as the specialist who studies the crop, will need to be informed regarding hybrids. Thus it seems worth while to place on record some of the more salient facts established by our studies of diversity among the hybrids of the Upland and Egyptian types of cotton, in order to show something of the relative importance of the different characters as evidences of hybridization.

STATURE AND METHODS OF BRANCHING OF HYBRIDS.

Many hybrid plants are conspicuous by reason of their more robust stature. Having greater vegetative vigor than the plants of unmixed descent they grow to larger size. Many robust plants are tall, so that they stand out, even at a distance, but in others the large size is attained by putting out more numerous spreading limbs.

The range in the size of hybrid plants is very wide. Small Upland-like plants 2 to 3 feet high are found (Pl. III, fig. 1) beside huge overgrown plants from 5 to 10 feet high (Pl. III, fig. 2).

A similar wide diversity occurs in the shape of the hybrids. Upright, symmetrical plants of the Upland type are found, but the tall, overgrown plants are constructed on an entirely different plan, usually having basal limbs as long as the main axis.

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PRIMARY BRANCHES OF HYBRIDS.

Hybrids often diverge from the pure Egyptian habits of growth in showing a more definite tendency to develop primary (axillary) vegetative limbs instead of forming vegetative limbs by modification of the secondary (extra-axillary) branches that would otherwise bear the fruit. The growth of two branches from the same node is more frequent in the hybrids than in pure Egyptian plants.

Many Upland plants put forth the primary limbs after the fruiting secondaries have developed. The usual habit of the Egyptian cotton seems to be to transform the lower secondaries into vegetative limbs, leaving the primaries entirely undeveloped, unless there has been a severe check or injury or the plant assumes more vigorous habits of growth after fruiting branches have already put out from the lower joints of the stem.

STRONG FERTILE BRANCHES OF HYBRIDS.

Upland cotton has relatively stronger and more horizontal fertile branches than the Egyptian. Hybrids often show this feature in a notable degree and then appear very different from the Egyptian plants. (Pl. III.) The latter usually have short and rather weak branches, which become drooping or pendent if they attain any considerable length. The branches of the Upland cottons and the strong-branched hybrids are borne down, of course, when the bolls become heavy, but this does not keep their relatively greater development from being apparent.

The greater tendency of the Upland cotton to put forth fruiting branches from near the base of the main stalk is often shown in the hybrids, even when the Egyptian tendency to develop limbs becomes predominant in the later growth of the plant and causes the lower fruiting branches to appear small and stunted. The unmixed Egyptian plants may also put forth small fertile branches at the base of the main stalk, especially if the plants do not grow too luxuriantly in the early part of the season. These low-fruiting branches often remain small and stunted if the plants change their habit of growth a little later, but some of the hybrids make this change less readily than the Egyptian cottons and thus show a larger development of the fruiting branches near the base of the central axis of the plant.

FOLIAGE OF HYBRID PLANTS.

The hybrid nature of many plants is made apparent by their leaves. Frequently the leaves have a distinct reddish tint, a character of

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Upland cottons. This color is often notably lighter than in the unmixed Egyptians. The light-colored plants usually have the leaves of rather thin texture and with broader, shorter lobes, usually borne in a more definitely horizontal position. This is likely to be true also of other hybrids whose leaves offer no other obvious marks of distinction except that they may have longer and more numerous hairs, especially on the lower surface. Hybrids can not be definitely distinguished from pure Egyptian plants by the texture of their leaves. The leaves may be thin and flexible, as in American Uplands, or even more thick and rigid than in pure Egyptian. Often they are of the texture of Egyptians.

The shape of hybrid leaves varies considerably, not only on the different plants but on the same plant, a condition of diversity more or less common to all cottons. The leaves on the main stalk and limbs are larger than those on the fruiting branches. Some leaves are more deeply cleft than others and the margins of some are crenate, which gives them a wavy outline. In some leaves the lobes are rounded, while in others they are acute.[a]

Three-lobed, five-lobed, and seven-lobed leaves occur, those on the main stem usually having the greatest number of lobes. The bases of the three-lobed leaves are generally oblique to the petiole and straight, while those of the five and seven lobed leaves are either rounded, cordate, or overlapping.

Few of the hybrids have either very hairy or entirely glabrous leaves. Many plants have the leaves hairy on the lower surface, but few bear leaves with hairs on their upper surface; occasionally a plant occurs with entirely smooth leaves. On sparsely hairy leaves the hairs are generally stellate, but on those more densely covered the hairs are simple. Marked hairiness on leaves or other parts of the plants is a clear indication of hybridity. It is considered in Egypt that a reddening of the base of the leaf is an indication of hybridization with the Hindi cotton.

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[a] Mr. H. M. Leake, of India, has investigated the leaf forms of hybrids between varieties of Indian cotton by means of what he calls the "leaf-factor," the ratio of length to width in the middle lobe. As a result of over 10,000 measurements he decides that the average ratios for the hybrids are intermediate between those of the parent types in the first generation. The application of this method to the second and later generations would be still more laborious, owing to the greater range of variation in these generations, and could have no practical value in the detection of hybrids, at least in the series studied by us, because many of them repeat the parental peculiarities or even exceed them. See Leake, H. M., Journal and Proceedings of the Asiatic Society of Bengal, January, 1908, p. 14.

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VARIED PHYLLOTAXY OF HYBRIDS.

The normal arrangement of the leaves and branches of both Egyptian and Upland cottons is a three-eighths spiral. Each leaf is separated from the leaf directly above it by eight joints of the stem. A spiral connecting the two leaves and passing through the bases of the intervening leaves makes three turns around the stem. Hybrids may show any one of four different spiral arrangements. Plants with a one-third, two-fifths, or five-thirteenths spirals should be taken as hybrids, though many hybrid plants may have the three-eighths arrangement as in the parent types.

This arrangement is characteristic of the main stem and of the vegetative branches. The leaves on the fruiting branches appear to alternate in a one-half arrangement on all plants, due to the twisting of the internodes to bring all the flowers on the upper side of the branch.

SIZE AND TEXTURE OF BRACTS IN HYBRIDS.

There is a great range in the size of the involucral bracts of hybrid plants. They vary from small bracts, which are often red and which approach most closely the Upland type in texture, to the large, green, bullate bracts with the stiff, brittle texture of the Egyptian plants. The enlarged bracts greatly exceed in size the bracts of either parent, corresponding with the overgrown condition of the hybrid on which they occur. Only the small hybrid plants which adhere closely to the Upland type in other characters bear bracts of pure Upland texture. The mature bracts of most hybrids are rather stiff and brittle, though frequently more pliable in the younger stages of growth than young Egyptian bracts. Because of their Egyptian-like texture the mature bracts on drying have a tendency to curl in like Egyptian bracts, and in this condition are hardly distinguishable from the Egyptian type.

CORDATE FORM OF BRACTS OF HYBRIDS.

Some of the most reliable characters for the ready distinction of the hybrids are to be found in the larger size and the broader and more cordate form of the bracts of the involucre. The bases of the bracts are extended downward each side of the flower stalk into broadly rounded lobes, so that the flower stalk appears to be inserted in a deep notch. In the Egyptian cotton the bracts have no such conspicuous broadening at the base and seldom extend much below the line of attachment to the flower stalk. (Pl. V.)

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LONG TEETH OF BRACTS OF HYBRIDS.

The marginal teeth of the bracts of hybrids are longer, broader, and more numerous than in unmixed Egyptian and are often hairy, at least along the margins. Conversely, the notches between the teeth are narrow and sharp in the hybrids instead of being broad and rounded as in the Egyptian cotton. Hybrids with well-developed bracts usually have from 12 to 14 teeth, while the normal number of teeth on the bracts of Egyptian ranges from 6 to 10. They are usually uniformly distributed, each tooth standing by itself, though infrequently three of them may be grouped at the apex, as in the Egyptian parent. The veins of the bracts are also more numerous in hybrids, to correspond with the larger number of teeth, and are generally more prominent, especially on the outer surface, while in the pure Egyptian plants the veins are more prominent on the inner surface of the bracts. (Compare bracts shown in Pls. IV and V.)

Though the numbers and forms of the teeth usually afford the best means of distinguishing hybrids they may give little assistance in difficult cases that approach closely to the Egyptian type. Sometimes the Egyptian forms and numbers of the teeth are preserved, the only sign of hybridity being the greater length of the teeth. In rare cases hybrids may even reduce the number of teeth below that of the Egyptian parent instead of increasing it. Thus at Yuma a hybrid plant was found in which some of the bracts had only 3 or 4 teeth, though others had 6 or 8, like the Egyptian parent. And yet in several other respects this plant showed distinctly Upland features. Even the bracts themselves, with the reduced numbers of teeth, were hairy on the outside, as in the Upland cotton.

REDDENING OF BRACTS OF HYBRIDS.

The outer surfaces of the bracts of many hybrids have a dull pinkish or reddish color, especially those exposed to the sun. This reddening often appears when the bracts are quite young. Sometimes it deepens with age, but on other plants only the young bracts show the reddish tinge. The tendency comes from the Upland cottons, where it is often very pronounced, while among the Egyptian cottons there is seldom any definite trace of it, though an occasional bract may appear somewhat reddish. Thus it may be said that any obvious reddening of the bracts gives reason for suspecting hybridity, and that any decided tendency to the red color is a fairly sure indication and likely to be accompanied by other obvious Upland features.

ABNORMAL FORMS OF BRACTS IN HYBRIDS.

Abnormalities in the form of the bracts are not infrequent in hybrids and are to be considered as one of the evidences of hybridity,

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especially when many abnormal bracts occur on the same plant. These abnormalities take many forms, but they all appear to represent intermediate stages between normal leaves and normal bracts. It often happens that the leaf at the base of the flower stalk takes on more or less the character of a bract. The slightest and most frequent indication of the change is seen when one of the stipules is enlarged. Sometimes both stipules are enlarged, and one or both of them may be joined to the reduced and shortened blade of the leaf, the petiole being more or less completely suppressed. Finally, bracts which are quite normal in other respects may have one or both of the lateral divisions, which represent the stipules, separated to the base, or the bracts may be in irregular positions or may be abnormal in number.

Involucres composed of only two bracts occur on some of the hybrids, but are not as frequent as in the pure Egyptian stocks raised from newly imported seed. Two-bracted involucres may or may not be accompanied by two-locked bolls. The four-bracted involucres which occur occasionally in Upland cottons have not been observed in the hybrids.

Next to the lint itself, the involucre probably represents the most highly specialized structure of the cotton plant. It is therefore not surprising that hybrids should show these irregularities in the forms of the bracts. Indeed, it seems rather remarkable that such irregularities do not appear in a larger proportion of the hybrids, in comparison with the parent stock. The plants grown from the seed obtained from Mr. Dale showed more frequent and striking examples of abnormality in the bracts than any of the hybrid stocks.

DISTINCT CALYX LOBES OF HYBRIDS.

In many hybrids the calyx, instead of having the nearly straight, even rim of the Egyptian parent, is definitely lobed, as in the Upland cotton. (Pl. V.) Sometimes the lobes are even sharper than in some of our Upland varieties. As in the Upland cotton the largest lobes are those that bear nectaries, those that stand opposite the openings between the bracts. A lobed calyx affords only corroborative evidence of hybridization, since it seems always to occur in connection with other more apparent hybrid characters, such as the broad, long-laciniate bracts. With white, bell-shaped flowers of the Upland type the calyx is constantly lobed, and these also have a prominent hairy rim above the internal nectary of the calyx, as in Upland cottons. The absence of lobes can not be accepted as evidence of pure blood, for plants with other distinctive features of hybrids may have no lobes on the calyx or only the very broadly rounded, scarcely appreciable scallops frequent among pure Egyptian cottons.

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A stronger development of the ring of hairs above the internal nectary of the calyx is also to be considered as an indication of Upland ancestry. This character seems to be especially prepotent in hybrids with Kekchi cotton.

LIGHT-COLORED FLOWERS OF HYBRIDS.

Many of the hybrid flowers share the pale, creamy white color of the Upland parent. This renders pale-flowered hybrids very conspicuous among yellow-flowered Egyptian plants and affords a ready means of separation. But, unfortunately, not all of the hybrids have the creamy flowers. In some of the hybrid plants the flowers are of a pale yellow, while others have them as dark as any of the Egyptian cottons.

PALE SPOTS ON THE PETALS OF HYBRIDS.

Many of the hybrids lack the dark reddish purple spot found at the base of each of the petals of Egyptian cottons, others have faint or broken spots, while still others have the spots as dark as in any of the Egyptians. The variations of the spot seem to be quite independent of those of the color of the petals. Though spots are most frequently absent in the light, creamy flowers, the pale flowers may also have very dark spots, or the deep yellow flowers may have faint spots, or none at all. If, in addition to this variability among hybrids, we consider the fact that pale petals and faint spots sometimes appear among the newly imported Egyptians, it becomes apparent that these color characters alone are not to be relied upon for distinguishing hybrids, except as they add to the evidence afforded by other features.

LARGE PETALS OF HYBRIDS.

Measurements show that the petals of hybrids are not only much larger than those of Upland cottons, but are generally larger than those of pure Egyptian plants. At Sacaton the petals of hybrids ranged from 2¼ to 3½ inches long by 1¾ to 2⅜ inches broad, while those of the pure Egyptian petals averaged distinctly smaller, ranging from 2 to 2⅜ inches long by 1½ to 2 inches broad. At Yuma the petals averaged smaller both in the hybrids and in the pure Egyptian flowers and the differences between the two were less. Though the hybrid flowers are usually larger than the Egyptian, large flowers are not a positive indication that the plant is a hybrid. Some hybrids have flowers which are smaller than many of the Egyptian flowers.

CUP-SHAPED FLOWERS OF HYBRIDS.

Hybrids with pale petals also share the Upland shape of the flower. The petals spread more widely apart near the base and give the

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flower a more open, cuplike shape, obviously different from the more cylindrical or tubular form of the Egyptian flowers, which never open so widely as those of the Upland cotton. This wider opening of the pale flowers increases the resemblance to the Upland parent, while hybrids with flowers of a deep yellow color usually have the complete Egyptian form as well. (Pl. VI.)

DARKENING OF OLD FLOWERS OF HYBRIDS.

The flowers of the Upland hybrids, though usually paler when fresh than the Egyptian flowers, turn darker with age, first becoming pink and then deepening into dull purple as the corolla shrivels and dries, whereas the old flowers of the Egyptian cotton usually remain yellow or darken only a little. This difference was very noticeable at Yuma, where Mr. Kearney had made use of it for distinguishing the hybrids, but at Sacaton it was found to be much less reliable, for many apparently pure Egyptian plants were found in which the old flowers had turned to a dull purple or were blotched and spotted with purple to nearly the same extent as in Upland varieties and hybrids at Yuma.

LONGER STAMENS OF HYBRIDS.

Many hybrids, and especially those with pale flowers, have the filaments or stalks of the stamens like those of the Upland cotton, much longer than in the pure Egyptian. (Pl. V.) These longer filaments require more room than the narrow tube of the Egyptian flower affords. This fact may help to explain the apparent correlation between the light color and more open Upland shape of the flowers. As the light flowers almost always have long stamens the more open shape may follow as a mere mechanical necessity.

Hybrids that have long stamens like the Upland parent do not show very plainly the regular Egyptian arrangement of the stamens in five double longitudinal rows. Other hybrids have the numbers of the stamens greatly reduced, and in these the rows may be very apparent. More or less complete abortions of the stamens are rather frequent in hybrids. The anthers may fail to develop to the full size or may appear to be fully formed and yet fail to open. With the long filaments of the Upland parent anthers of the smaller Upland type are usually associated.

PALE POLLEN OF HYBRIDS.

Pollen grains of very irregular sizes are often found in the anthers of hybrids, and sometimes there appears to be a distinct diversity of color, though this is not easy to determine, because the apparent color of the grains differs so much in different lights, even when the color

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is really uniform. Pale-flowered plants usually have the pollen also of a pale creamy or yellowish shade, while the pollen of yellow-flowered plants often shows the deep orange of the Egyptian parent.

THICKENED STYLES OF HYBRID FLOWERS.

The style is uniformly thicker in white-flowered hybrids; nearly as thick as in the Upland type. In some hybrids the styles are as short as in the Upland cottons, while in others they are intermediate in length between the Upland and the Egyptian. They are seldom as long as in pure Egyptian. (Pl. VI.)

PEA-GREEN BOLLS OF HYBRIDS.

Many hybrids can be distinguished at once by the light pea-green color which renders the bolls obviously different from the dark-green bolls of the Egyptian. The lighter shade of green is largely due to the fact that the oil glands are fewer in number or more deeply sunken and covered with green tissue, as in Upland cotton, instead of being exposed on the surface as in the Egyptian. (Pl. V.)

Bolls that have the light color almost always show something of the large size and more broadly pyramidal shape of the bolls of Upland cotton and thus appear the more distinct from the narrower and more cylindrical bolls of the Egyptian. Nevertheless, there appears to be a complete series of gradations in sizes, colors, and shapes. Plants shown by other characters to be hybrids may bear bolls which by themselves would appear genuinely and typically Egyptian. As already noted in the discussion of the Egyptian varieties, they show a much greater amount of diversity in boll characters than would be expected in any well-bred Upland variety. This adds, of course, to the difficulty of using boll characters as a means of distinguishing hybrids, except in the cases where the lighter color and different texture of the surface are obvious.

FIVE-LOCKED BOLLS OF HYBRIDS.

The bolls of hybrid plants are able to show the complete range of diversity of the parent types. Many hybrids have 2 to 4 locks, like the Egyptian parent, while others have 3 to 5 locks, like the Upland parent. Five-locked bolls are so rare a phenomenon in Egyptian cotton that they are always to be considered as an indication of hybridity. Nevertheless, it has not been necessary to reckon any plant as a hybrid because of this character alone, for it seems never to appear in a hybrid except in connection with other obvious Upland features. Five-locked bolls seldom appear singly; where one is found, several others are to be expected if the plant is at all productive.

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Sometimes the number of five-locked bolls nearly equals that of the four-locked, but such cases are not common. Plants with numerous five-locked bolls are likely to have very few with three locks or none at all. When there are no five-locked bolls an absence of three-locked bolls or any notable preponderance of the four-locked bolls over the three-locked may serve to call attention to a hybrid. There is said to be a popular impression in Egypt that even four-locked bolls are found only on hybrids. This may be true in districts where the plants attain only small size.

The representation of five-locked bolls among the Egyptian hybrids in Arizona appeared to be distinctly less than in the hybrids between Kekchi cotton and Egyptian, which had been studied previously in Texas. Some of the long-staple Upland varieties have very few five-locked bolls, but there had also been opportunities of crossing with big-bolled varieties, where five-locked bolls are usually more numerous than in the Kekchi. It is possible that the five-locked tendency is more effectively inherited from the Kekchi cotton or that the difference represents an influence of the external conditions, which have been found to have definite effects upon the number of locks.

TWO-LOCKED BOLLS OF HYBRIDS.

Hybrids often exceed the pure Egyptian plants in the proportion of two-locked bolls. At Sacaton the bolls of pure Egyptian plants were quite consistently three-locked, the proportion of two-locked bolls being notably less than on many plants which were obviously hybrids. It seemed at Sacaton that any large number of two-locked bolls was as good an indication of the hybrid nature of a plant as a similar abundance of four-locked bolls. An average of 4.6 per cent of two-locked bolls was found on seven pure Egyptian plants. The highest percentage for any one plant was 12, and this plant also had the greatest number of two-locked bolls. Some of the hybrids are as consistently three-locked as any of the pure Egyptian plants.

At Yuma Messrs. Kearney and Peterson had formed an impression that the number of two-locked bolls was greater in 1908 than in previous seasons, which would accord with other indications of less favorable conditions for the cotton. Seven of ten plants of acclimatized Mit Afifi at Yuma were found to have two-locked bolls in the average proportion of about 5 per cent, nearly the same as at Sacaton. Of ten plants taken at random in a plot grown from imported Mit Afifi seed nine had two-locked bolls—in the general proportion of 13.4 per cent. Similarly striking reductions in the numbers of locks of the bolls have been found to take place in Central American varieties when first introduced into Texas.

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FUZZY SEEDS OF HYBRIDS.

A majority of hybrid plants have their seeds covered with long dense fuzz. The color of the fuzz varies from green through the different shades of brown to white. A large proportion of the hybrids can be distinguished by the long dense fuzz, but this is by no means a safe guide in all cases. Very fuzzy seeds were found, as already described, in the newly imported Egyptian cotton, and on the other hand many hybrids have seeds more completely naked than the seeds of the pure Egyptian. Indeed, Mr. Kearney has noted among some of his special selections that the smooth seeds of hybrids fall into a rather distinct class. There appear to be very few hybrids with the same amount of fuzz that is usual in the Egyptian cotton. Those that have less fuzz than the Egyptian usually have much less or none at all.

A plot grown by Mr. E. W. Hudson at Sacaton, Ariz., from carefully selected smooth seeds contained nearly as large a proportion of obviously hybrid plants as a row that had been planted from a selection of the fuzziest seeds. Many plants grown from the fuzzy seeds showed no definite indications of hybridity, and the seeds of these plants in many cases bore as little fuzz or less than those of pure Egyptian plants. Plants were also found in other fields that had densely fuzzy seeds, but no other hybrid characters. The full range of diversity in seeds of hybrids is from perfectly smooth to densely fuzzy, fully covering the range of diversity for both the parent types and extending beyond.

Plants that appear distinctly degenerate in the strength of the fiber or in the number of seeds in the lock often have seeds that are completely devoid of fuzz. On the other hand, many of the very smooth-seeded hybrids at Yuma had fiber that was excellent in strength and in all other characters, comparing very favorably on the average with the lint from the fuzzy-seeded hybrids.

SIZE OF HYBRID SEEDS.

The seeds of hybrids range in size from that of Egyptian to an accentuated size larger than that found in Upland cottons. Hybrid seeds which come within the range of diversity for fuzziness in the seeds of newly imported stock may exceed the imported seeds in weight by 1 or 2 grams to the hundred. The majority of fuzzy seeds are of the size of Upland seeds, but some are of enormous size, nearly twice as large as those of Upland. In Kekchi × Egyptian hybrids the seeds are very large and have green fuzz in the first generation, these features tending to disappear in the second and third generations.[a]

[a] Cook, O. F. "Reappearance of a Primitive Character in Cotton Hybrids," Circular 18, Bureau of Plant Industry, U. S. Department of Agriculture. 1908.

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It seems to be a general rule that fuzzy seeds attain a larger size than those that have less fuzz. The largest of the fuzzy seeds were selected from six different lots and found to average larger than the largest of the seeds that remained.

Weights of fuzzy and normal seeds.

[Stated in grams per 100 seeds.]

Weight of selected fuzzy seeds.	Weight of largest of remaining seeds not unusually fuzzy.	Weight of selected fuzzy seeds.	Weight of largest of remaining seeds not unusually fuzzy.
Grams.	*Grams.*	*Grams.*	*Grams.*
17.06	14.46	17.55	14.11
16.91	14.78	17.67	13.93
17.96	14.48	15.93	15.30

In five of the six cases there was a notable difference in favor of the fuzzy seeds. It is perhaps worthy of note that the figures showing the smallest inequality were derived from a plot which consisted largely of hybrids. Here the fuzzy seeds were smaller and the non-fuzzy larger than elsewhere.

SUPERIOR LINT OF HYBRIDS.

One of the notable peculiarities of the hybrids lies in the fact that the lint of the first generation hybrids is often superior to that of the pure Egyptian plants. The proportion of first generation hybrid plants having very long, fine, strong lint is also notably higher than among the pure Egyptian plants. At the same time hybrids are frequently to be found which are as bad or worse than the poorest of the Egyptians, with very short, very sparse, or very weak "perished" lint.

The superiority of the good hybrids is so striking as to lead all observers to raise at once the question of establishing a hybrid stock as a substitute for the pure Egyptian. At the same time it has to be admitted that there is nothing to warrant the hope of practical success in this direction. The diversity among the hybrids is too great and experiments have not yet shown that uniformity can be secured, even by many generations of selective breeding.

Nevertheless, another possibility of utilizing hybrids in the production of cotton of very high grade remains to be considered. Experiments with crosses between Egyptian cottons and Central American varieties belonging to the Upland series have shown that the lint of first generations of hybrids is superior to that of the subsequent generations and very much more uniformly good in the individual plants. These facts suggest that a culture based on first generation hybrids might have better prospects of practical success than the attempt to

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develop hybrid stocks. With a type of cotton so different from the Egyptian as the Kekchi, it would not be difficult to produce first generation hybrids on a commercial scale. The small size of the Kekchi plants and their broad-lobed hairy leaves would enable them to be separated very readily from the more robust and smoother hybrid plants, so that only hybrids need be allowed to grow to maturity.

The quality and uniformity of the crop might be still further guarded, if necessary, by selection in the field, for the larger size and greater fertility of the hybrid plants would make field selection very easy and expeditious. Indeed, such field selection of lint would involve much less difficulty than the careful selection of seed plants required to maintain the superiority of any carefully tried variety of cotton like the Sea Island or Egyptian.

The most serious objection to the staple furnished by the hybrids is that it usually lacks the brownish tinge, which is one of the commercial characteristics of most of the grades of Egyptian cotton that are imported into the United States. If this feature is important enough to make a difference in the price it may be possible to obtain darker hybrid lint by using a brown strain of the Kekchi cotton as the female parent of the hybrids.

Observations made by Mr. Kearney upon hybrids between the Egyptian cotton and several varieties of the Upland series appear to indicate that such crosses have less uniformity in the seed characters in the first generation than has been obtained in our experiments with the Kekchi cotton. Thus, of 280 Egyptian-Upland hybrids recorded at Yuma 124 had smooth seeds, while 156 had fuzzy seeds. No such proportion of smooth seed has been noted in the Kekchi-Egyptian hybrids, where smooth seeds are very rare in the first generation.

It has been noted already that smooth-seeded hybrids often have weak lint, whereas fuzzy-seeded hybrids, like those formed with the Kekchi cotton, generally have strong lint. Even when the lint becomes short or sparse it usually remains very strong. Fuzzy-seeded hybrids with weak lint were not noticed in the field at Sacaton, but Mr. Kearney's records show a case of this kind from Yuma. The character of the very fuzzy seeds of the Kekchi cotton seems to be much more strongly prepotent in hybrids with the Egyptian cotton than the corresponding character of the Upland varieties, though the presence of smooth seeds in some of our Upland types may help to explain this apparent difference.

PRINCIPAL CHARACTERS FOR DISTINGUISHING HYBRIDS.

For practical purposes it is possible to give a list of several characters which are sufficiently definite to serve as guides in eliminating

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hybrids. Any one of these characters affords a sufficient ground for rejecting a plant as a hybrid, but in addition to the plants which may be recognized by these characters it will be good policy, in the interest of maintaining a pure stock, to reject any individual that shows a notable difference from its neighbors either in habits of growth or in any definite detail of form or color of foliage, flowers, bolls, seeds, or lint.

Breeders may have more difficulty than practical farmers in discarding hybrids. The farmer who is interested only in keeping his stock pure can at once rogue out any unusual plant, while the breeder will need to be very careful to avoid the danger of discarding a valuable sport on a mere suspicion that it may be a hybrid.

Following is a list of the most obvious and reliable characters for distinguishing hybrids:

(1) Cordate, hairy, involucral bracts, with numerous (12 to 14) teeth.
(2) Large, cup-shaped, white flowers, with pale petal spots or no spots at all.
(3) Large pea-green bolls.
(4) Bolls with five locks or a large percentage of bolls with four locks (25 per cent or upward).
(5) Densely fuzzy, large seeds.
(6) Hairy leaves, leaf stems, or branches.
(7) Calyx with triangular pointed lobes.

CORRELATIONS OF CHARACTERS IN HYBRIDS.

An effort was made to detect correlations of characters in the hybrids as a further means of deciding the question of hybridity in doubtful cases. If in all plants known to be hybrids or definitely recognizable as such a character were always found to be combined with some other character, there would be less reason to believe that a plant was a hybrid when only one of these characters appeared. Such correlations might assist in determining whether any particular plant represented a first generation hybrid or a later generation, for the study of other cotton hybrids has shown that fairly definite correlations may appear in the first generations which are broken up in later generations.[a]

In first generation hybrids between Egyptian cotton and the Kekchi cotton of Guatemala the seeds are almost always larger than those of either parent and these larger seeds are always covered with very dense bright-green fuzz. In later generations this grouping of characters is broken up. The seeds return to normal size and the green fuzz tends to disappear, giving place to the white fuzz of the

[a] That external conditions may also have a notable influence upon the expression of characters in hybrids has been shown in a previous report, "Suppressed and Intensified Characters in Cotton Hybrids," Bulletin 147, Bureau of Plant Industry, U. S. Department of Agriculture. 1909.

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Kekchi parent or to the naked black seed of the Egyptian parent. Whether because the Egyptian is the female parent in the present hybrids or because the fuzzy character of the Upland cotton is less prepotent than that of the Kekchi cotton the coordination of seed characters appears not to be so definite.

Nevertheless, it appears to be possible to group a large proportion of the hybrids into a few series characterized by fairly definite complexes of characters. All that can be claimed for the present is a probability that the different combinations of characters stand in fairly definite relations to fertility and lint production. As a basis for further study of the subject, brief descriptions of a few of the principal types have been drawn.

SYNOPSIS OF PRINCIPAL TYPES OF HYBRIDS.

The following are the principal types of hybrids:

(1) Limbs stiff, erect, very upright, with short internodes; bolls small and lint inferior.

(2) Limbs upright, somewhat spreading, with long internodes; bolls large, 3-locked, 4-locked, and sometimes 5-locked; lint abundant and usually long.

(3) Limbs spreading, main axis generally strong and erect; bracts broadly cordate; flowers pale; bolls of Egyptian type; lint usually buff and like Egyptian in quality.

(4) Plants lower and more spreading or prostrate, with long internodes; bolls numerous, 4-locked and 5-locked; lint long; seed well linted.

(5) Plants of Upland habit of growth; bolls mostly 4-locked and 5-locked; seed usually large and fuzzy; lint abundant, but short.

TYPE I OF HYBRIDS.

The plants of Type I are tall and strictly upright. The basal limbs equal or exceed the main stem in length, are stiffly erect, and make a compact growth. The leaves are generally large, not deeply lobed, and often wrinkled or bullate. The fruiting branches are slender, short, and infertile, and usually bear only one or two small bolls with only a few seeds. The lint is short and very sparse, and covers only a small area at the upper end of the seed. The bracts are broad, deeply cordate, with rather short but narrow láciniæ. The flowers are pale, with faint petal spots or none at all. These might be called "degenerate hybrids."

TYPE II OF HYBRIDS.

Type II is distinguished by excessive vegetative growth, long internodes, large five-lobed leaves, long ascending fruiting branches, and broad, cordate bracts of the Upland type. The plants may be either very productive or nearly sterile. The bolls are long and pointed like Egyptian, but are mostly four-locked and much larger

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than Egyptian, and differ further in their pale pea-green color. The seeds are large and well covered with rather long lint, which is usually longer and less abundant on smooth than on fuzzy seeds. The flowers are larger than in Egyptian, petals pale yellow, and their basal spots faint. The filaments of the stamens are long, as in Upland, and the stigma is often shortened, protruding only slightly beyond the long stamens. The calyx is shorter than Egyptian and sharply lobed like Upland cotton.

Three forms of plants might be distinguished in this type, differing in the development of the basal branches as compared with the main axis:

(1) The first class has short, weak, spreading, basal limbs, but a very strong, upright, main axis. Sometimes late in the season primary limbs develop from the main axis near the top of the plant and bear branches.

(2) The second class differs from the first only in having two or three longer, more upright basal limbs. These first two types have strongly developed fruiting branches and are very productive.

(3) The third type has several very strong limbs, as long as the main axis. The fruiting branches are weak and bear few bolls.

TYPE III OF HYBRIDS.

Of the five types of hybrids Type III is the most like Egyptian. The plants are Egyptian in form, having the strong, slightly spreading basal limbs as long as the main axis. The bolls are three-locked and dark green. The lint is buff. The hybrid plant is distinguished from the Egyptian mainly by its larger size, broad, cordate bracts, and rather pale flowers. The bolls are enlarged and the seeds are large and generally fuzzy. Such plants are usually infertile.

TYPE IV OF HYBRIDS.

Type IV includes the most productive and the most abundantly linted plants in the hybrid series. The plants are more spreading than the Egyptians, having a strong main axis with long, widely spreading or prostrate basal limbs. The fruiting branches are horizontal. All internodes are long. The leaves are rather large, five-lobed, and generally hairy on the lower surface. Other distinguishing features are broad, cordate bracts, faint petal spots, a predominance of large, four-locked and five-locked bolls, and large seeds. The lint is abundant and fine; smooth seeds bear a longer staple than fuzzy seeds. Most of the plants have red stems, but a few green-stalked plants occur. Some of the plants are more upright or more compact than others, but apart from these slight differences there is a very consistent agreement in characters, often extending to minute particulars.

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TYPE V OF HYBRIDS.

The fifth type includes the small Upland-like plants which can be easily detected as hybrids by their small size and hairy Upland-like leaves. Only the main axis and the fruiting branches are developed to any extent, the basal limbs being suppressed or remaining short and spreading. The bolls are large, four-locked and five-locked, light green, and with shallow gland pits. The seeds are large and usually fuzzy, with abundant, rather short, but often fine lint. The flowers are as light as Upland, with either faint or dark spots, very large anthers, cream-colored or whitish pollen, and stigmas protruding only slightly, if at all, beyond the stamens.

CONCLUSIONS.

The general practical conclusions regarding the nature and causes of diversity have already been stated in the introduction as the best means of indicating to the reader in advance the point of view from which our studies were made.[a] The following paragraphs constitute a somewhat more detailed summary of the facts that have been established, with indications of their bearings upon the problems to be solved and methods to be used in this and other similar investigations.

The Egyptian and Upland cottons belong to the same general series of American types and are capable of showing similarly wide ranges of diversity, especially when grown under new and unwonted conditions. This community of origin and parallel behavior warrants a tentative application to the Egyptian cotton of facts and principles learned in the study of the acclimatization of tropical American cottons in the United States.

Studies of Egyptian varieties grown at Yuma from imported seed show many forms of diversity that would not be expected to appear in carefully selected varieties and would usually be ascribed to hybridization. In the plantings of Arizona-grown Egyptian seed this diversity appears to have increased rather than to have diminished, even after the exclusion of all individuals that can be distinguished as hybrids.

The difficulty of acclimatizing Egyptian cotton is increased by the fact that the varieties have been distinguished thus far by lint characters alone, with little or no reference to the vegetative features. Selection for long lint has not reduced the diversity of forms, and

[a] The practical aspects of the experiments with Egyptian cotton in the season of 1908 have been treated by Messrs. Kearney and Peterson in Circular No. 29 of the Bureau of Plant Industry, published April 16, 1909.

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the crossing of these varied forms with each other tends to prolong the condition of diversity instead of hastening the completion of acclimatization.

To secure prompt acclimatization, selection should have reference to the normal behavior of the plants rather than to new characters or to special excellence in particular characters. Acclimatization is to be distinguished both in aims and in methods from the selective breeding by which new and improved varieties are obtained.

Incomplete acclimatization renders the plants unusually susceptible to differences of external conditions. Different parts of the same field often show serious differences in the fertility of the plants, as well as in the length, strength, and abundance of the lint. These discrepancies appear out of proportion to the differences in the conditions as shown by the size and vegetative vigor of the plants, but can be understood if we remember that fertility and early bearing depend upon the habits of branching which the individual plants may adopt and that such habits are readily influenced by external conditions.

Additional diversity is occasioned by the appearance in the Egyptian fields of numerous hybrids between the Egyptian cotton and the Upland. The presence of so many hybrids is explained by the fact that the cotton flowers at Yuma are visited by insects which are apparently more numerous and active than at any other points where cotton experiments have been described, either in the United States or in foreign countries. Such insects will render it practically impossible to maintain pure stocks of Egyptian seed if Upland cotton is grown in the same localities.

Hybrid plants, at least in the first generation, are usually more fertile than the pure Egyptian plants and produce longer and stronger lint. In spite of the diversity of vegetative characters among the hybrids their lint is commonly more uniform in length and strength than that of the pure Egyptian plants, though distinctly different from the pure Egyptian fiber. In later generations of hybrids degenerate plants occur, infertile and inferior in lint.

The very high grades of lint that may be obtained from first generation hybrids and their extreme vigor and productiveness warrant the consideration of means for obtaining hybrid seed in commercial quantities. A possibility of producing fields of hybrid plants lies in the fact that certain of the characters of Egyptian cotton are strongly prepotent, especially in the first generation. Thus, if the Egyptian were crossed on the small Kekchi type of Upland cotton the young hybrid plants could readily be distinguished from the Kekchi plants and the latter removed in the process of thinning the seed-

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lings. To recognize the young hybrids among Egyptian seedlings would be much more difficult, if not actually impossible.

This possibility of utilizing hybrids should not be allowed to obscure the fact that hybrids are a distinct disadvantage in fields of Egyptian cotton because they interfere with the uniformity of the lint. The elimination of hybrids is rendered very difficult by the fact that many of them show no perceptible differences in their vegetative characters and habits of growth to distinguish them from the pure Egyptian plants before the involucres and floral buds have developed. Nevertheless, it is necessary that the hybrids be eliminated as soon as they begin to flower; otherwise their pollen will infect the next generation. To reject the seed of hybrid plants does not completely purify an Egyptian stock that has once been hybridized.

The preceding considerations make it evident that Upland cotton must either be excluded from regions when Egyptian cotton is to be grown, or local sources of supply of pure, acclimatized Egyptian seed must be established and very carefully guarded from contact with Upland cotton if commercial cultures of Egyptian cotton are to be permanently maintained in Arizona and the neighboring States. Even if a culture based on hybrids should prove feasible it would still be essential to maintain pure stocks of the parent types to continue the production of the hybrid seed.

The diversity in the behavior of Egyptian cotton at the different places where it was grown this year shows that it may not suffice to complete the process of acclimatization in any one locality if this seed is to be planted afterwards in any other localities. It should not be supposed that the possibilities of growing Egyptian cotton in a new locality can be judged from a single planting. Even after acclimatization has been completed and the industry established, it will still be necessary to take into account the need of adjustment to local conditions whenever the crop is to be extended to a different district.

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PLATES.

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DESCRIPTION OF PLATES.

The illustrations used for these plates were furnished by Mr. Kearney. The photographs were taken at Yuma, Ariz., at the end of the season (October 7–13, 1908), when the plants were fully mature.

PLATE I. Fig. 1.—Egyptian cotton. An acclimatized plant showing the form taken when a strong central stalk is developed. Vegetative branches rather small; fruiting branches large. Fig. 2.—Egyptian cotton. A plant from newly imported seed showing the form taken when there is a strong development of the vegetative branches. Fruiting branches small and unproductive; no fruit on lower half of plant.

PLATE II. Fig. 1.—Egyptian cotton. A plant showing an intermediate development of branches, the central stalk and vegetative branches both bearing numerous fertile branches. Fig. 2.—Egyptian cotton. A large and very fruitful plant bearing more than 300 bolls. Branches equal to main stem, but likely to be bent or broken to the ground by the weight of the fruit.

PLATE III. Fig. 1.—Egyptian-Upland cotton hybrid. A small plant with the habit of growth of Upland cotton. Bolls pea-green in color, borne mostly near the bottom of the plant, smaller than usual in hybrids; lint very abundant. This plant represents the fifth type of hybrids. Fig. 2.—Egyptian-Upland hybrid. A tall, vigorous, fertile plant, showing long fruiting branches and greater fertility at the base of the plant; also showing Upland features of pea-green bolls and green fuzzy seeds. This plant represents the second type of hybrids.

PLATE IV. Egyptian cotton, Mit Afifi variety, grown from newly imported seed. Bracts and bolls from several different plants to show range of difference in shape and markings. The bracts show the typical Egyptian form with the three middle teeth somewhat abruptly prominent. The calyx of the boll with the bracts is split and is not to be confused with the lobes of the calyx of the hybrid shown in the next plate. (Natural size.)

PLATE V. Mature unopened bolls of first generation hybrid of Egyptian and Upland cottons at Yuma. The larger size, more pyramidal shape, smaller and more shallow pits, and pea-green color afford ready distinctions. (Natural size.)

PLATE VI. Fig. 1.—Flower from an Egyptian plant and a flower from a hybrid plant, showing a broader and more cup-shaped, shorter corolla. Fig. 2.—Staminal columns of Egyptian flowers, with short filaments and long styles. Fig. 3.—Staminal columns of hybrid flowers, showing the longer filaments and shorter, thicker styles characteristic of the hybrids. (Natural size.)

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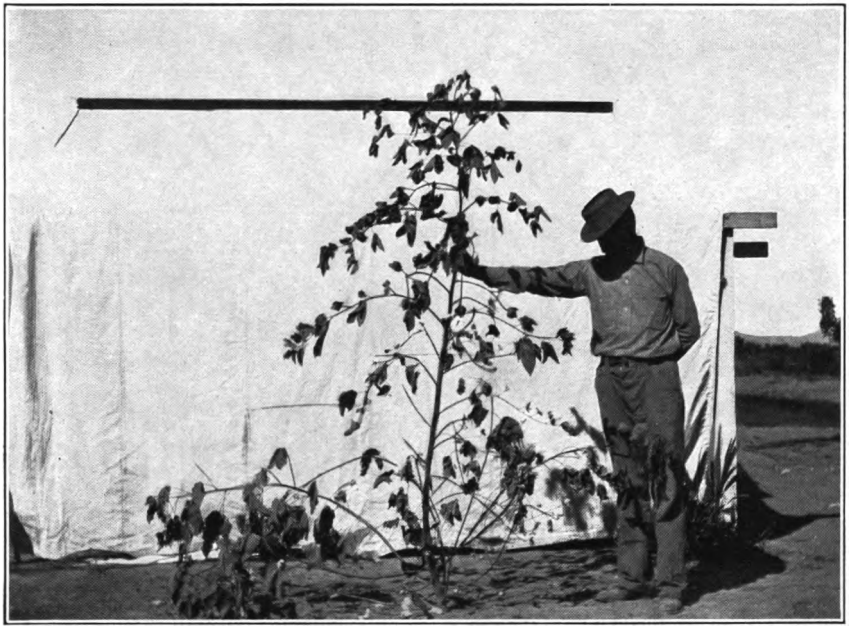

FIG. 1.—FERTILE PLANT OF EGYPTIAN COTTON, SHOWING STRONG CENTRAL STALK AND LONG FRUITING BRANCHES.

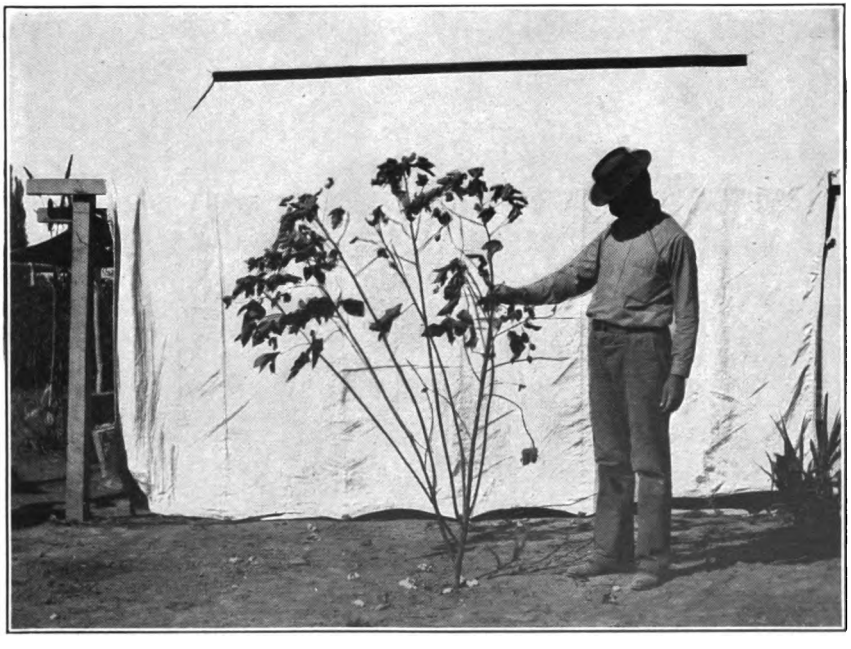

FIG. 2.—PLANT OF UNPRODUCTIVE TYPE OF EGYPTIAN COTTON, SHOWING NUMEROUS VEGETATIVE BRANCHES AND VERY SMALL FRUITING BRANCHES.

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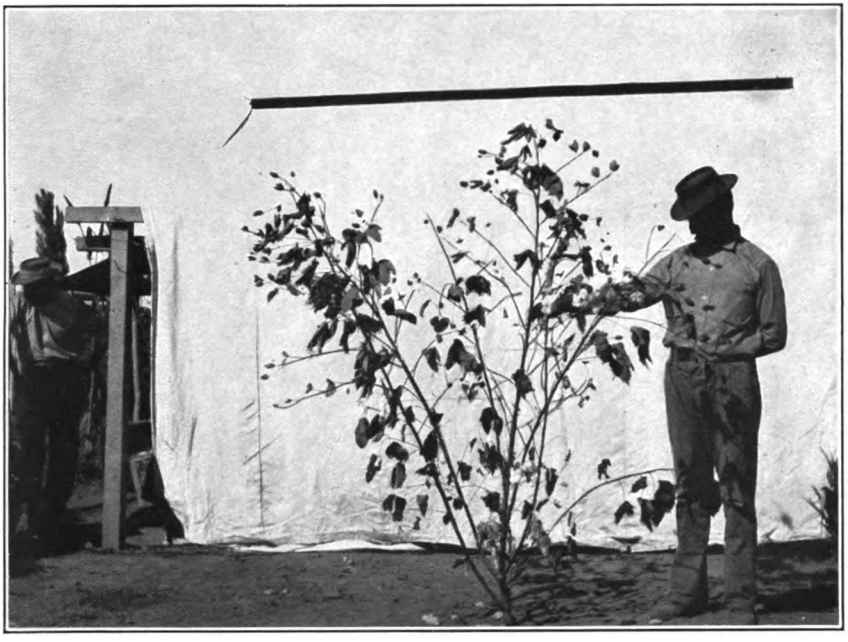

FIG. 1.—MODERATELY PRODUCTIVE PLANT OF EGYPTIAN COTTON, WITH BOTH VEGETATIVE AND FRUITING BRANCHES WELL DEVELOPED.

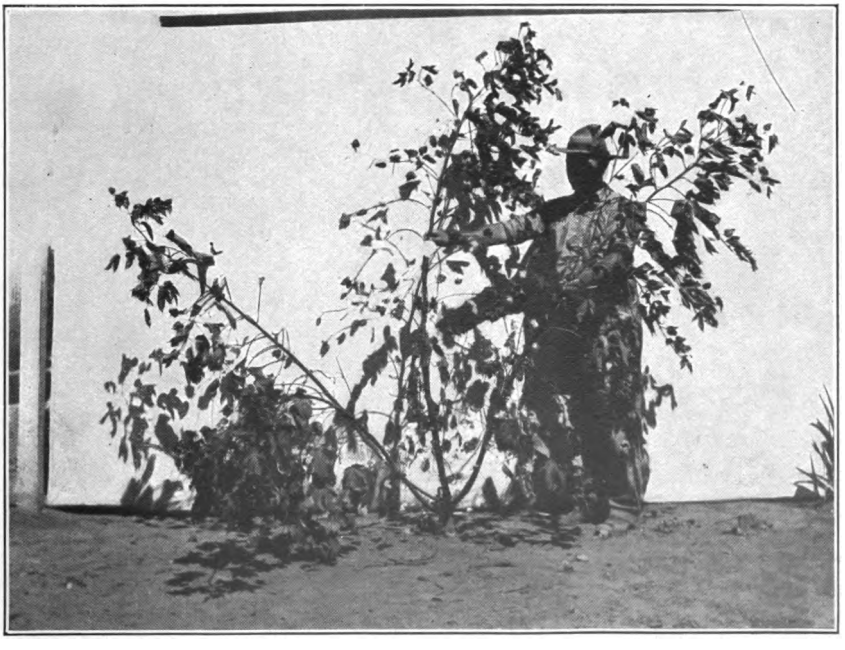

FIG. 2.—VERY PRODUCTIVE EGYPTIAN COTTON PLANT, WITH ABUNDANT FRUITING BRANCHES.

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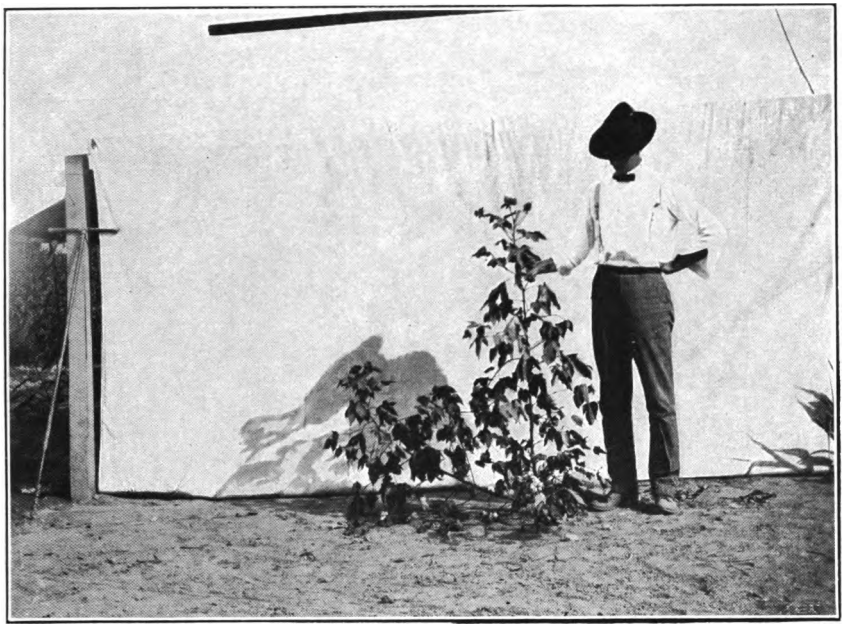

FIG. 1.—EGYPTIAN-UPLAND HYBRID. A SMALL PLANT OF THE UPLAND TYPE.

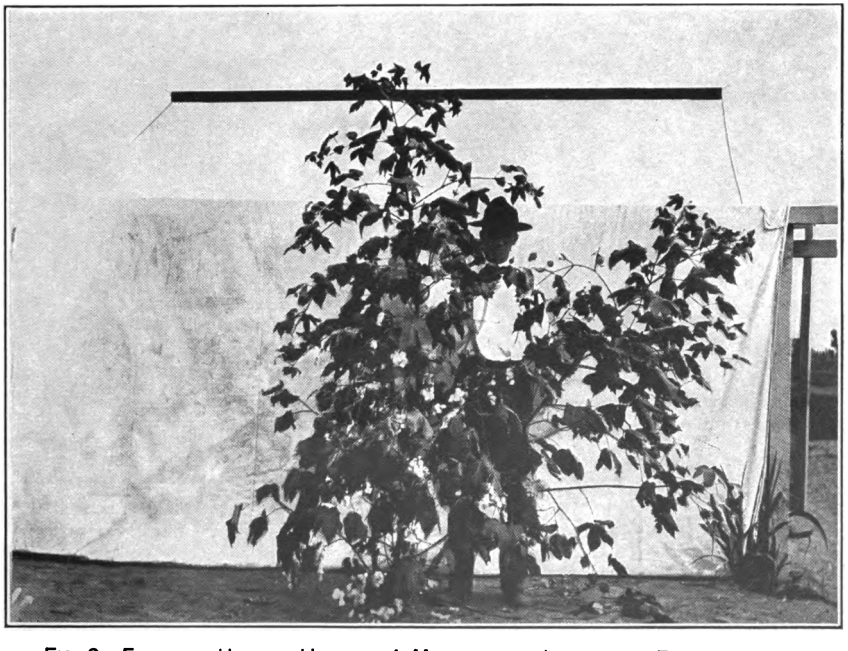

FIG. 2.—EGYPTIAN-UPLAND HYBRID. A MODERATELY LARGE AND FERTILE PLANT.

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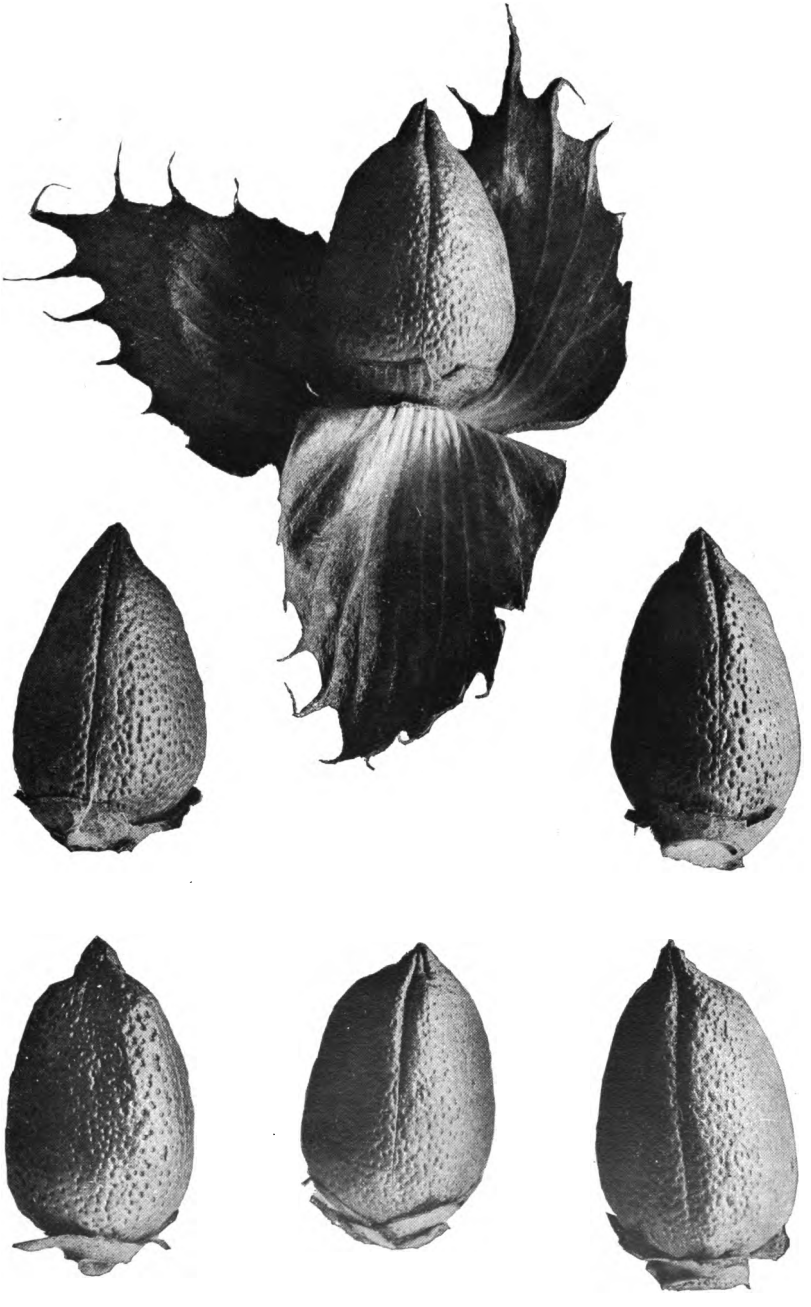

BOLLS AND INVOLUCRAL BRACTS OF MIT AFIFI EGYPTIAN COTTON GROWN IN ARIZONA.
(Natural size.)

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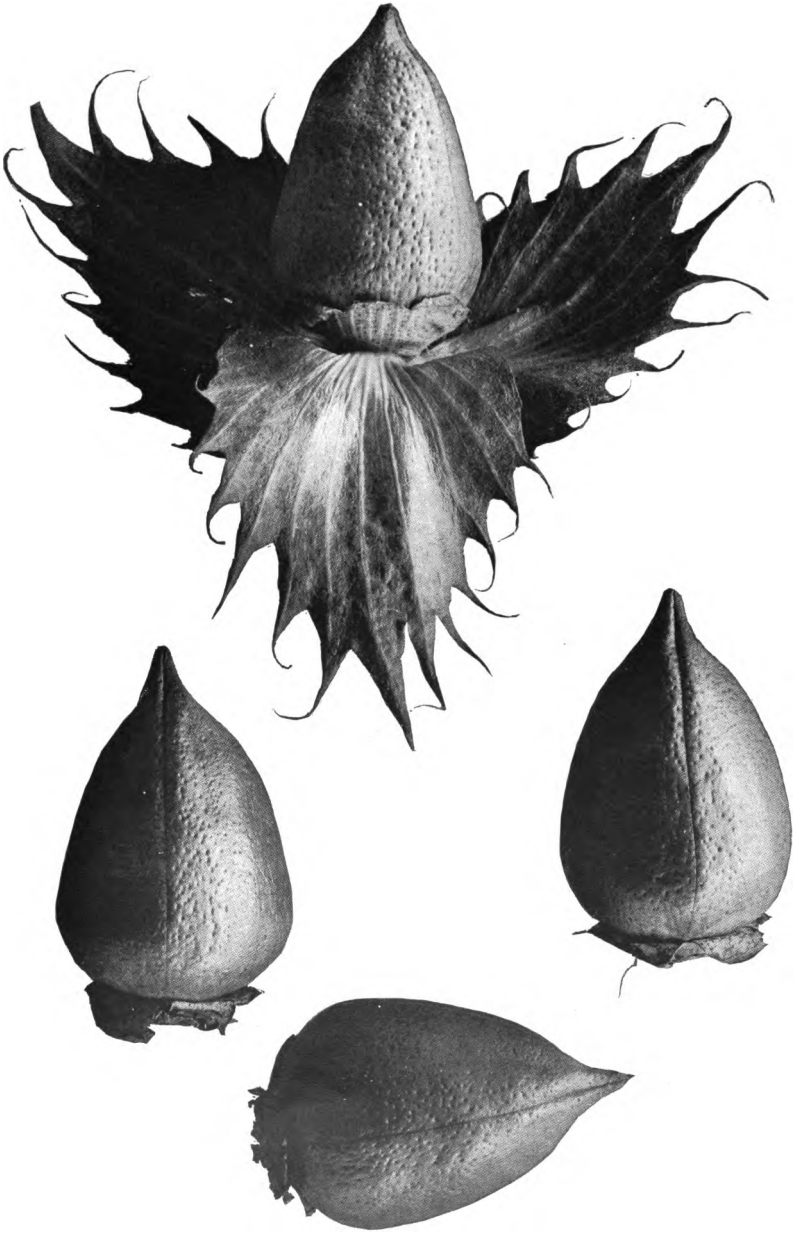

BOLLS AND INVOLUCRAL BRACTS OF EGYPTIAN-UPLAND HYBRID COTTON WITH STRONG RESEMBLANCE TO UPLAND PARENT.

(Natural size.)

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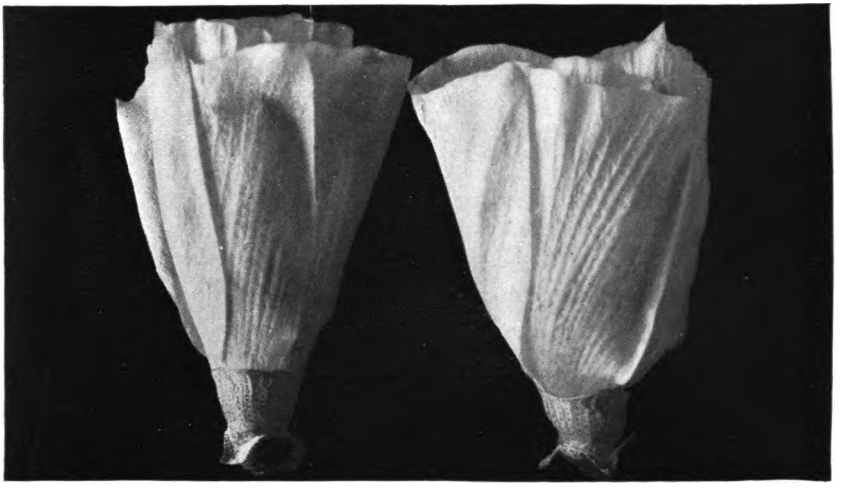

FIG. 1.—FLOWER OF EGYPTIAN COTTON AND FLOWER OF EGYPTIAN-UPLAND HYBRID.
(Natural size.)

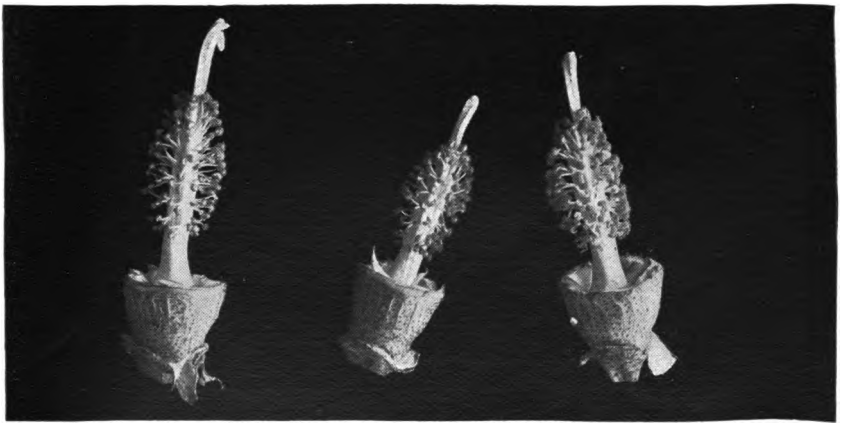

FIG. 2.—STAMENS AND STIGMAS OF EGYPTIAN COTTON.
(Natural size.)

FIG. 3.—STAMENS AND STIGMAS OF EGYPTIAN-UPLAND HYBRIDS.
(Natural size.)

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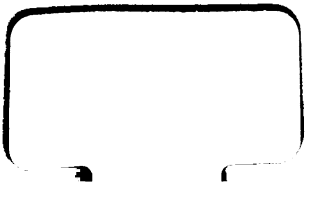

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